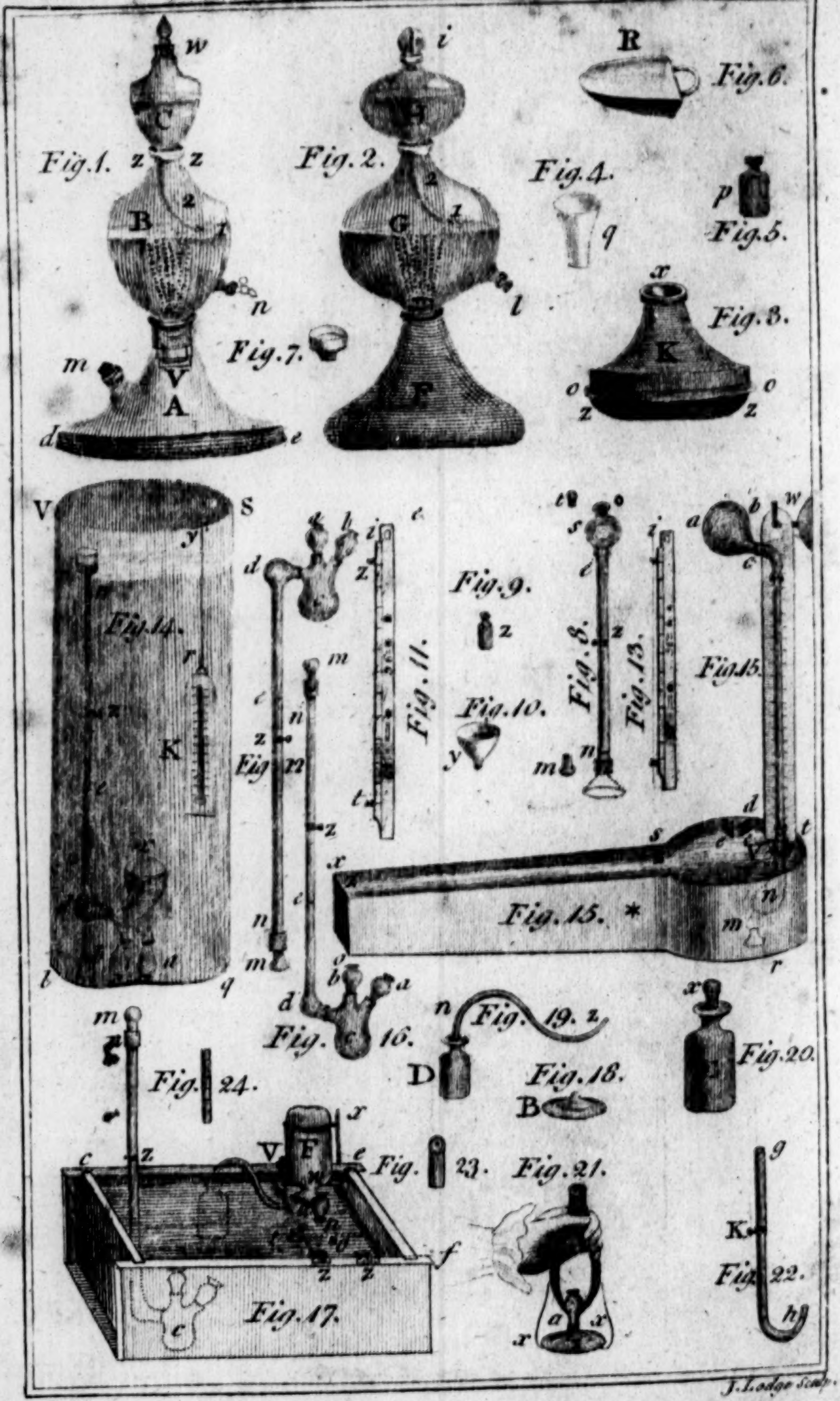

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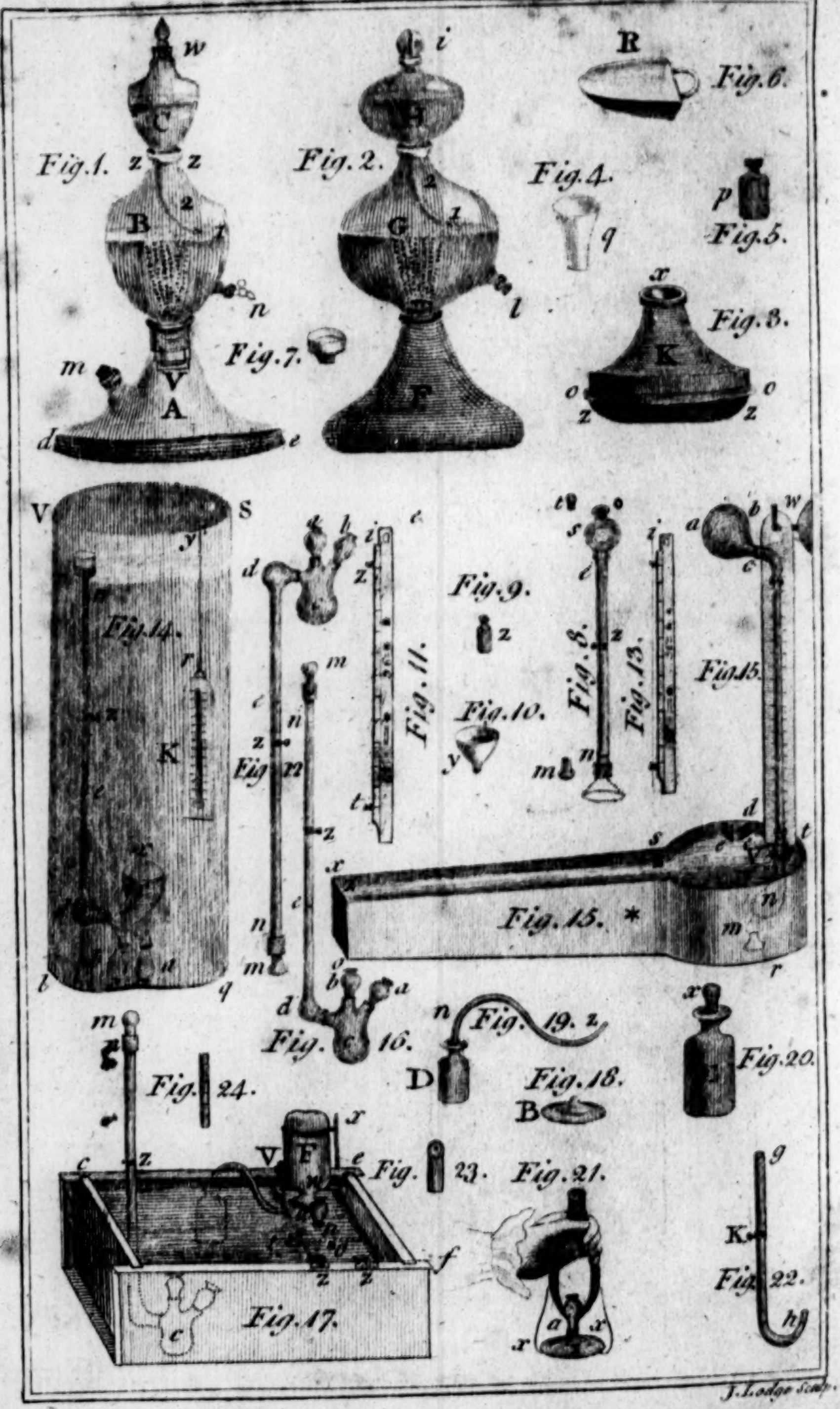

J. Lodge Sculp.

For the British Museum of London

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DESCRIPTION
OF A
GLASS APPARATUS
FOR MAKING
In a few MINUTES, and at a very ſmall EXPENCE,
THE BEST MINERAL WATERS
OF
PYRMONT, SPA, SELTZER,
SEYDSCHUTZ, AIX-LA-CHAPELLE, &c.
TOGETHER WITH THE DESCRIPTION OF TWO
NEW EUDIOMETERS,
Or INSTRUMENTS, for aſcertaining the
Wholeſomeneſs of RESPIRABLE AIR,
And the Method of uſing theſe INSTRUMENTS,
IN A LETTER TO THE
REV. DR. J. PRIESTLEY, LL.D. F.R.S.

By J. H. de MAGELLAN, F.R.S.

F.

The THIRD EDITION, Reviſed, Corrected, and
Enlarged by the AUTHOR, with an Examination of
the Strictures of Mr. T. CAVALLO, F.R.S. upon
theſe EUDIOMETERS.

LONDON:
PRINTED FOR THE AUTHOR,
MDCCLXXXIII.

ex dono auctoris

ADVERTISEMENT

Upon the Uſe of the *Simple Glaſs-Machines* for making the *beſt Mineral Waters.*

ALTHOUGH the method of uſing the *ſimple glaſs-machines*, is minutely deſcribed in the following Letter; nevertheleſs it may be more convenient to find here at once, diſtinct references to thoſe articles, where it is particularly contained.

I. The deſcription of the *ſimple machine* is compriſed, No. 5, 6, and 7.

II. The proceſs to make uſe of the ſame, No. 8, 9, 10, and 11.

III. The manner of carrying-on the production of *fixed air*, No. 12.

IV. The method for reducing the proceſs to a few minutes, No. 15. See note *g*.

V. How to keep, or preſerve a long time, theſe *mineral waters*, No. 16.

VI. To make them ſparkle, like *Champaigne wine*, No. 17.

VII. To render them *ferrugineous*, or *Chalybeate*, No. 18. and following.

VIII. As to the medical and oeconomical application of theſe waters, and of *fixed air*, See No. 1. 3. 19. 21, and following.

IX. To make the beſt *Pyrmont waters*, No. 28.

X. To make the beſt *Spa-waters*, No. 29.

XI. To make the beſt *Seltzer-waters*, No. 30.

XII. To make the beſt *Seydſchutz-waters*, No. 31.

XIII. To make the beſt *Aix-la-Chapelle waters*, No. 32.

XIV. Remarks on this *new branch of Medical Profeſſion*, No. 33.

N. B. All theſe *Glaſs-Apparatuſes*, and *Eudiometers*, are made and ſold at
W. Parker's Cut-glaſs Manufactory, No. 69.
Fleet-Street, London.

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TO THE

REV. DR. PRIESTLEY.

DEAR SIR,

I Do not know how better to employ the leiſure of theſe holy-days I enjoy in your neighbourhood, than in deſcribing, according to my promiſe *(a)*, the two contrivances I have mentioned in my laſt letter; which, I hope, will be uſeful to the public. It is with pleaſure I have obſerved a great agreement in almoſt all our philoſophical ideas; but I am very happy to find that we agree ſtill more, in looking with the greateſt indifference on any

---

(a) This refers to the P.S. of a former letter to Dr. Prieſtley, printed in the Appendix to his Third Volume of Experiments and Obſervations on Air, No. III. p. 376, of the London edition.

diſ-

diſcovery, even the moſt ingenious, if no real advantage may accrue from it to mankind. Amongſt the many that you have made, and which are ſcattered in your Philoſophical Works, that of producing by art, at any time or place, with very little expence and trouble, Mineral Waters, like thoſe of Pyrmont, Spa, Saltzer, &c. whoſe chief virtues depend on their being impregnated with *fixed air*; and that of finding out a general ſtandard, or teſt, for aſcertaining the greater or leſs ſalubrity of reſpirable air, in any place whatſoever, are, undoubtedly, the moſt beneficial. The ſucceſs with which the firſt of theſe two diſcoveries is employed, wherever it is known, and the very intereſting obſervations relating to the ſecond, made almoſt all over Italy by the Chevalier Landriani, with his Eudiometer, clearly evince the truth of my obſervation (*b*).

2. As ſoon as your pamphlet, containing the method of making Pyrmont Water, fell into

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(*b*) Dr. William White of York, has made in England many valuable obſervations of this kind, part of which were communicated to the Royal Society; and a very able phyſician of Florence, Dr. Alexander Bicchierai, has undertaken, with other friends, to make daily obſervations with the eudiometer, in different parts of Italy; conſidering this, as a branch of the utmoſt importance in the meteorological regiſter of the weather.

my hands, in the year 1772, I ſent abroad a great many copies of it, to different parts of Europe, where I have a literary correſpondence; this having long been my cuſtom, whenever any uſeful diſcovery comes to my knowledge. I made then ſome change or improvement in your method, which rendered the manner of conveying the fixed air to water ſomewhat eaſier. This was added in a note to the french tranſlation of it, made ſoon after at Paris, from a copy that I had ſent to that great promoter of Natural Philoſophy, the late Monſieur Trudaine de Montigny, mentioned pag. 268, of your 2d vol. on Diff. Kinds of Air. See pag. 324, vol. 2, of *Introd. to the Journal de Phyſique*. Some time after, Mr. Blunt invented a machine, which rendered this operation ſtill more eaſy. One of this kind, made by himſelf at Mr. Nairne's, I ſent to a very judicious lover of philoſophical experiments at Turin, the Marquis de Roſignan, lately ambaſſador of the king of Sardinia to the Court of Berlin.

3. Another conſtruction of a glaſs machine for the ſame purpoſe, was publiſhed by Dr. Nooth, in the 65th vol. of Philoſophical Tranſactions. But this being very imperfect, was afterwards improved by Mr. Parker; and you have given an account of it in the ſecond vo-

lume of your work, abovementioned, page 293, and foll. 2d edit. A very great number, [many thouſands] of theſe machines have been ſent to different parts, even to the Eaſt-Indies; and it is known that many perſons have been greatly benefited by the uſe of theſe artificial acidulous waters *(c)*.

4. I found, however, not long ago, that the manner of conducting the proceſs, as deſcribed in the printed directions ſent with theſe machines, was very inconvenient, on account of it's ſlow operation; it requiring four, and even ſix or ſeven hours to get the water fully impregnated with fixed air. This I felt the more in November laſt (1776) on my being at his Serene Highneſs's the Duke of Arenberg, whom I have a right to call my Mæcenas, on account of the many favours I have received from him *(d)*.

Know-

(c) See Profeſſor Bergman's excellent Treatiſe *De Aquis Artific. Frigidis*, vol. I. of his *Opuſcula*, § 19, pp. 223, & ſeq. and Dr. Withers's Obſervations on Chronic Weakneſs, in 8vo. p. 164. printed at York, 1777.

(d) Alas! this truly great Prince is no more! He fell a ſacrifice to the ſmall-pox, that evil ſo vaſtly deſtructive to the human ſpecies. Thinking himſelf ſecure on account of ſome few of the diſcreet kind, which he had in his infancy, he did not avail himſelf of the great bleſſing of our times, inoculation, through which ſo many thouſands, or rather millions, have been reſcued from death.

This

Knowing this generous prince to be endowed with the beſt diſpoſitions that any of his rank ever had, for encouraging and giving his protection to all improvements and diſcoveries beneficial to mankind, this conſideration prompted me to ſend from London, one of theſe improved machines to Bruſſels, for the uſe of his highneſs; and, on my trying it, after my arrival there, I felt, for the firſt time, how diſagreeable it was to wait ſo long for the deſired effect; which could be ſoon compleated, if the firſt method already mentioned

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This great Prince died the 17th of Auguſt, 1778, in the 57th year of a glorious life, generally employed for the good of his ſubjects, and the happineſs of every one, who had any dependence upon, or acquaintance with, this true friend to mankind. He was the patron of all ſciences, a lover of all polite arts, and the promoter, as well as the warm protector of all uſeful knowledge.

It is now (1783) five years ſince this Prince has been numbered with the dead! and dead indeed!—For though his heroic deeds, and his public as well as his private virtues, claimed to be reſcued from oblivion, as a pattern of emulation to poſterity; not one, to my knowledge, of the many that were aſſiduouſly courting his favours, or that were benefited by his generoſity, not one, I ſay, have publiſhed to the world the leaſt account of his extraordinary qualities either as a Man or a Prince! A good leſſon to the Great, were they wiſe enough to learn from others, how to ſelect thoſe on whom they confer their friendſhip, or beſtow their favours.

(No. 2.) was employed: for which reaſon, I always had made uſe of this laſt, in preference to any other; as it requires but few minutes to compleat the operation.

I then conſidered what could be done to avoid this. At laſt I contrived the following apparatus, conſiſting of ſome additional pieces, by which means the whole operation is ſo ſhortened, as to take but few minutes: and, at the ſame time, the quantity of the artificial water is increaſed to the double of that, which is impregnated, at one proceſs, in the ſimple glaſs-machine, improved by Mr. Parker.

DESCRIPTION *of the* SIMPLE GLASS-MACHINE.

5. A B C (fig. 1,) repreſents one of the improved machines of Mr. Parker, ſtanding upon a wooden diſh *d e*, in order to prevent any water, if ſpilled, from falling on the table. The middle veſſel B has a neck, which is inſerted into the mouth of the veſſel A, being nicely ground air-tight to it. This lower neck of the middle veſſel B, has a ſtopple V of glaſs, compoſed of two parts, both having holes, ſufficient to let a good quantity of air paſs through them: between theſe two parts is left a ſmall ſpace, containing a plano-convex

lens, which acts like a valve, in letting the air paſs from below upwards, and hindering the fall of the water into the veſſel A. This glaſs ſtopple was invented by my good friend Mr. Benj. Vaughan.

6. The upper veſſel C terminates below in a tube, marked 2, 1, (fig. 1,) which being crooked, hinders the immediate paſſage of the bubbles of fixed air into the upper veſſel C, before they reach the ſurface of the water in the veſſel B. The veſſel C is alſo ground air-tight to the upper neck of the middle veſſel B; and has a ſtopple *w*, fitted to its upper mouth, which either is perforated through the middle, as *w* and *i* (fig. 1 and 2,); or is of a conical form, without any hole. But it will be better to have that kind of ſtopple, which will be hereafter deſcribed, No. 17. This upper veſſel C contains nearly half the water that can be contained in the under one B; and the end (1,) of it's crooked tube (2, 1,) goes no lower than the middle of the ſame veſſel B. Each of the veſſels, A and B, have an opening, *m* and *n*, with ground ſtopples, which are only open when occaſion requires, as will be mentioned hereafter.

But after the laſt edition of this letter, a glaſs-cock has been adapted to it inſtead of the ground ſtopple *n*, (beſides the veſſel B being ſhaped in a more elegant form); which is repreſented by points at *n* in fig. 1.

7. Fig. 2. repreſents the two veſſels B and C, upon a wooden ſtand F, whilſt ſeparated from the veſſel A.

Fig. 4. repreſents a wide glaſs-funnel *q*, which may enter into the upper mouth of the veſſel A.

Fig. 5. repreſents a ſmall phial *p*, which ſerves to meaſure the quatity of the vitriolic acid to be made uſe of.

Fig. 6. repreſents a little trough of tin R, to meaſure the pounded chalk or marble, that is to be employed in every proceſs.

And, fig. 7. repreſents a particular kind of ſtopples, the uſe of which will be explained hereafter, No. 17.

The PROCESS *with the* SIMPLE-MACHINE.

8. Let ſome dry chalk, as it comes out of the earth, that is to ſay, raw, without being burned in the fire; or rather white marble,

which is much better for the purpoſe *(e)*, be reduced to powder; and let ſome oil of vitriol be at hand. The veſſel *B*, together with *C*, (fig. 1.) muſt be taken off from A, and put on the wooden ſtand F. (fig. 2.) Let the veſſel B be filled with ſpring, or any other drinking water, or even with diſtilled water; and let it be joined again with the upper veſſel C.

9. Let ſome water be poured on the lower veſſel A, ſo as to cover the riſing part of its bottom: but, if this appears too vague a direction, pour in fourteen or ſixteen meaſures of water, with the glaſs *p* (fig. 5.) : then fill the ſame phial *p* with oil of vitriol, and pour it into the ſame veſſel A, along with the water.

(*e*) White marble being firſt granulated, or pounded like ſmall gravel, is much better for this purpoſe, than the pounded chalk; becauſe the action of the diluted acid upon the marble, laſts a very conſiderable time; and the ſupply of *fixed air*, which is diſengaged by this efferveſcence, is much more regular than otherwiſe. In general it continues to furniſh *fixed air*, more than twenty-four hours. When no more air is produced, if I decant out of the veſſel A, all the acid fluid, already ſaturated; and waſh off the thin, white, gypſeous ſediment: I may employ again the remaining granulated marble, by adding to it freſh water, and a new quantity of vitriolic acid; which will then furniſh a further ſupply of *fixed air:* and this may be repeated over again, until all the marble is diſſolved; which will not be very ſoon.

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It will be, however, much eaſier to have made beforehand the mixture of oil of vitriol and water, in the above proportion. In this caſe, it will not be liable to ſuch bad conſequences, as ſometimes happen with ſtrong oil of vitriol, which, if ſpilt, burns and deſtroys almoſt every thing it meets with. But when weakened by the mixture of about 14 or 16 times its own bulk of water (or even twenty times its bulk, if the oil of vitriol is well concentrated) it will hardly be able to do any miſchief, no more than the juice of lemons, vinegar, or any other ſuch acid, *&c.* It is true that its bulk becomes greatly increaſed: but its carriage will be ſafer, and its value very conſiderably cheaper to the purchaſer.

10. After the acid is poured into the veſſel A, let the glaſs-funnel *q* (fig. 4.) be put into the ſame veſſel: and filling the ſpoon *R* (fig. 6.) with the pounded chalk or marble, let it be thrown into it. Take off the funnel *q*, which is uſed only to prevent the chalk from touching the inſide of the mouth of this veſſel; ſince otherwiſe it would ſtick ſo ſtrongly to the neck of the veſſel B, as not to allow the taking it off again without breaking. Then place immediately the two veſſels B and C, as

they are, over the mouth of the veſſel A: and all the *fixed air* which is diſengaged from the chalk or marble, by the force of the diluted acid, will paſs up, through the valve V, into the veſſel B. When this *fixed air* comes to the top of the veſſel B, it will diſlodge from thence as much water as its bulk: and this water, ſo diſlodged, will go up, by the crooked tube 2, 1, into the veſſel C.

11. Care muſt be taken not to ſhake the veſſel A, ſoon after the powdered chalk is poured in, and the veſſel B ſhuts up the veſſel A; for it will cauſe a great and ſudden efferveſcence, which will, perhaps, expel part of the contents. If this happens, it will be neceſſary to open the ſtopple *m*, in order to give vent to the efferveſcence for a moment; otherwiſe the veſſel A may chance to burſt. Perhaps it will be neceſſary to throw away the contents, to waſh the veſſel with water (becauſe the boiling matter will ſtick between the necks of theſe veſſels, and will cement them together), and to begin the operation afreſh. But if the powdered chalk is thrown in, without any conſiderable ſhake of the machine, there will be but a ſmall effervеſcence at the beginning. When this operates well, the veſſel *C* will ſoon be filled with water, and the veſſel *B* half filled with air; which, when done, will

be eaſily perceived, by the air going up in large bubbles by the crooked tube 1, 2. This will take place in about two or three minutes.

12. Whenever the effervеſcence nearly ceaſes in the veſſel A, it will be revived again by giving it a gentle ſhake, ſo that ſome part of the powdered chalk which is in a heap at the bottom of A, might be mixed with the diluted vitriolic acid, and diſengage more *fixed air*. However, when it happens that the whole is exhauſted, and no more air ruſhes up to the middle veſſel from the lower one; either more powdered chalk muſt be put in, or more oil of vitriol; or at laſt more water, if neither of the two firſt produced the deſired effect. Theſe additions may be performed by letting them in, either through the opening *m*, or through the mouth of the veſſel A. In this caſe, uſe muſt always be made of the funnel *q*, in order to avoid the ſticking of the junctures above-mentioned. If theſe veſſels be ſuffered to ſtand ſix or ſeven hours, the water will be ſufficiently impregnated, without any further trouble, provided the ſupply of *fixed air* be copious: and ſtill more ſo, if it is there compreſſed any way (*f*). It will be of ſome advantage to ſhake

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(*f*) When the ſtopple *w* is ſolid, of a conical form, and well ground on the upper neck of the veſſel C, it then ſhake the whole apparatus very gently, once or twice in every hour: in this caſe, the water may be impregnated by the *fixed air*, in five hours, and perhaps leſs. It was, however, to avoid even this delay, that I invented the following additional veſſels, by means of which the whole operation is conſiderably ſhorter.

DESCRIPTION *of the* NEW DOUBLE MACHINE.

13. Beſides the two veſſels B and C (fig. 1.), I have added two others perfectly alike, repreſented by G and H (fig. 2.). The veſſel H is furniſhed with a ſtopple *i*, either of a conical form, or equally perforated as the other *w*: this veſſel contains half as much as the veſſel G. Both theſe veſſels are ſet upon the wooden ſtand F; and the lower neck of the veſſel G is not only furniſhed with a valve and ſtopple, as already deſcribed, No. 5, ſpeaking of the veſſel B; but it is fitted, and ground air-tight, to the neck of the ſame veſſel A; and has an opening *l*, with a ground ſtopple, which is only opened when occaſion requires, as will be mentioned hereafter.

The wooden ſtand *K* (fig. 3.) is ſo contrived, that a thick piece of glaſs *x*, like a ſmall tum-

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then greatly contributes to forward the impregnation by it's preſſure; as will be ſeen by and by, No. 17.

bler, be cemented in the top *s*, after it has been ground air-tight to the under neck of the veſſels B and G. The form of this ſtand is eaſily conceived by fig. 3: it is partly flat in the bottom *z z*: turns up in a kind of convexity *z o* towards it's edge: and has a round moulding *o o*, which hinders it's tumbling, when moderately puſhed ſideways.

The PROCESS, *with the* DOUBLE GLASS-MACHINE.

14. The two middle veſſels B and G (fig. 1 and 2.) are to be filled with pure water, and put on the ſtands K and F, with their upper ones C and H, as in the figure. The mixture of oil of vitriol, water, and powdered chalk, or rather marble, muſt be done in the ſame manner, as was ſaid at No. 9: and finally the veſſels B and C are to be put on the veſſel A, as was ſaid No. 10, and following. But as ſoon as the veſſel C is filled with the water, thrown up by the air, which diſlodges it from the veſſel B, through the crooked tube 1, 2: both theſe veſſels B and C are to be removed together as they are, from the veſſel A to the ſtand K (fig. 3.), and the other veſſels G H, which are in the ſtand F, are to be put in their ſtead, upon the veſſel A. Whilſt the

operation is going on in theſe laſt, you muſt hold the veſſels B C, which are in the ſtand K, by the neck and ſtopple *w* with your right-hand, and by the under neck V with your left: incline them a little ſideways, and ſhake them very briſkly, ſo that the water within B be very much agitated, preſenting many freſh ſurfaces in contact with the *fixed air*; the greateſt part of which will be abſorbed into the water: as it will ſoon appear, by the end of the crooked tube being conſiderably under the ſurface of the water in the veſſel B.

15. It will ſuffice to ſhake the water in this manner during two or three minutes; which done, looſen the upper veſſel C, ſo that the remaining water may fall into the veſſel B; and the unabſorbed air may go out (*g*). Then taking off theſe veſſels from the ſtand K, put

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(*g*) By this method, even the ſimple glaſs-machine, above-mentioned, may be worked ſo, as to have the water fully impregnated with the *fixed air*, in a few minutes, though with leſs advantage. To do this, the veſſel B and C are taken off from the veſſel A: and holding them with both hands, they are to be ſhaken about a quarter of a *minute*; then after placing them again in the veſſel A, the upper veſſel is taken off a little, that the water therein may ſubſide again into the veſſel B: when a freſh ſupply of *fixed air* is produced, ſo as to fill half of the veſſel B, the ſame operation of ſhaking the two veſſels B and C is to be repeated four or ſix times: and the water in the veſſel B will be ſufficiently impregnated with the *fixed air*.

them, joined together as they are, on the ſtand F. By this time the veſſel G will be half filled with *fixed air*; and the upper veſſel H will be filled with the water thrown up by it. Take then theſe veſſels to the ſtand K, and replace the others B C on the mouth of the veſſel A, after letting out the unmixed air, as aforeſaid; ſo that theſe veſſels may be half filled again with fixed air, whilſt the water in the veſſels G H is briſkly ſhaken in the ſame manner as the others have been.

When this operation has been repeated three, or at moſt four times alternately, with each ſet of veſſels, throwing out the remaining air which does not incorporate with the water, after it has been briſkly ſhaken, and adding freſh quantities of *fixed air*, with which it be well agitated; in this caſe, the water contained in both the veſſels B and G, will be fully ſaturated in a few minutes.

16. Theſe artificial mineral waters are much more pleaſant to taſte, than the natural Pyrmont or Seltzer's waters, which, beſides their *fixed air* (the only part perhaps which affords their renowned virtues, and which is hardly half of what this artificial water can abſorb), contain ſome diſagreeable ſaline taſte; and it is known that this alone does not con-

tribute at all to their medicinal virtues; but on the contrary, it may be hurtful in ſome complicated caſes.

The artificial waters will remain as limpid and as tranſparent as before, although there has been abſorbed above as much air as their own bulk. The whole proceſs will hardly take above a quarter of an hour, by this method; and the quantity will be double of that which could be made in the ſimple glaſs-machine.

The water may be taken out by the opening *l* or *n*, to be drank immediately; if not, it will be better to let it remain in the machine, where it has no communication with the external air; otherwiſe, the fixed air goes off by degrees, and it becomes vapid and flat; as it happens alſo to the natural acidulous waters. Theſe artificial waters may, however, be kept a very long time, in bottles well corked, placed with their mouths downwards.

17. In general, they are ſo ſimilar to the natural acidulous waters, that they may be even made to ſparkle, like Champaigne wine. Mr. Warltire has actually brought theſe waters to this ſtate, by keeping the fixed air compreſſed upon the ſurface of the water in the

middle veſſel; as appears by his letter printed in the Appendix to your third volume of *Experiments and Obſervations on Air*, page 3t6. The ſame end will be obtained, if, inſtead of the ſtopples *w* and *i*, uſe is made of the ſolid one repreſented (fig. 7.), which has a kind of a baſon at the top, in order to hold ſome additional weight. This ſtopple muſt be of a conical figure, and very looſe; but ſo well ground and ſmooth in its contact, as to be air-tight by its preſſure, which may be increaſed by ſome additional weights in its baſon. If the veſſels are ſtout enough, there is no danger of their burſting in the operation, unleſs the weight be enormous.

18. Theſe waters may alſo be rendered ferrugineous (or chalybeate) very eaſily, by putting, in the middle veſſel, two or more ſlender phials, like that repreſented fig. 23, filled with cuttings of iron-binding wire, or ſmall iron nails, but without any ruſt: the impregnated water will diſſolve the iron ſo faſt, as to become well ſaturated with it in a few hours, according to the experiment of Mr. Lane. If the iron nails, or the cuttings of wire, were not confined in the ſmall phials, but ſet looſe in the middle veſſel; their ruſt or ſediment would ſtop the paſſages of the *fixed air* from the under veſſel: and in ſuch a caſe

the veſſel A muſt burſt; and the whole machine will be broken to pieces.

19. According to Sir John Pringle, there may be added to each pint of theſe waters, from eight to ten drops of *tinctura martis cum ſpiritu ſalis*, in order to reſemble more nearly the genuine Pyrmont water. But I will give hereafter (No. 25.) the true method for making the beſt Artificial Mineral Waters, extracted from the Treatiſes of that great Philoſopher and moſt famous Chemiſt of Upſal, Sir Torbern Bergman.

20. The method of rendering chalybeate theſe artificial waters, uſed by Dr. Hulme, is to add one grain of ſalt of ſteel to each pint (16 ounces) of water, already impregnated with fixed air.

21. There is no doubt but theſe artificial waters may be advantageouſly employed in many medical purpoſes; not only by diſſolving in them the very ſalts, which are found to be contained in many natural ſprings, renowned for their different virtues; but alſo by applying them ſimply without any other mixture. The ſame able phyſician Dr. Hulme has lately publiſhed (after the firſt edition of this pamphlet,) *An Account of different Caſes and Experiments,*

ments, by which it clearly appears, that *fixed air*, adminiſtered internally, has a powerful action for diſſolving the ſtone in the bladder, and againſt nephritic complaints. Its efficacy is equally beneficial againſt the ſcurvy *(h)*, the gout, the fevers, even the hectic ones with conſumption, the dyſentery, and the worms *(i)*.

22. Theſe artificial waters may be even applied as a vehicle to many draughts, and internal medi-

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(h) This I am able to teſtify on my own experience: for being attacked myſelf by ſcorbutic pains in all my limbs, a ſhort time after the ſecond edition of this letter, and my complaint being totally miſtaken by ſome of the faculty whom I had conſulted, I happily met with my good friend, and excellent phyſician Dr. Snowden White of Nottingham, who really diſcovered what it was. By his advice, I took this medicine of Dr. Hulme's, according to the preſcription tranſcribed in the following note *(i)*: and in leſs than a week's time, I began to find a very ſenſible relief: at the end of a month or ſix weeks, the pains of my limbs were removed, and I was able to walk, and to do any thing elſe, without the leaſt inconveniency; though before that time, I could not make a ſtep, nor hold any thing faſt with my hands, without a very painful ſenſation in all the joints that were exerted in the action.

(i) Dr. Hulme's preſcription is to take fifteen grains of ſalt of tartar, diluted with three ounces of pure, or of diſtilled water, four times a day: drinking immediately after, at every time, the ſame quantity of water impregnated with twenty drops of weak ſpirit of vitriol. See his Treatiſe, intitled, *A Safe and eaſy Remedy*, &c. in 4to. London, 1778, at G. Robinſon's and P. Elmſly's.

medicines, which will be the leſs nauſeous to the patients, and perhaps more agreeable to the ſtomach, giving to it a tonical ſtrength.

23. The advantages derived from *fixed air* in œconomical purpoſes, deſerve to be taken notice of in this place. Sir William Lee and his neighbours at Hartwell, did preſerve fleſh meat perfectly ſweet for ten days, which was as long as they had occaſion for, in the laſt hot weather of this ſummer (1778), one of the hotteſt we ever had in this country; and this was obtained by waſhing the meat, two or three times a day, with water impregnated with *fixed air*; even meat that had begun to change, was totally recovered by the ſame proceſs, as the ſaid gentleman aſſerted in a letter I have ſeen, directed to a friend of mine.

24. I ſhall conclude this ſubject by obſerving with you, that fixed air may be given to wine, beer, cyder, and to almoſt any liquor whatſoever. Even when beer has become flat, or dead, as it is called, it may be revived by employing the ſame method: however, the delicate, briſk, and agreeable flavour, or acidulous taſte, communicated by the fixed air, and which is ſo manifeſt in water, will hardly be perceived in wine, or other liquors, which have much taſte of their own.

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Method of preparing different MINERAL WATERS *by art, which have greater medical virtues than the natural ones.*

25. That great chemiſt and profound philoſopher, Sir Torbern Bergman, Profeſſor at the univerſity of Upſal in Sweden, has made the niceſt and compleateſt analyſis of ſeveral mineral waters, renowned by their medicinal virtues in Europe, which are publiſhed in the firſt volume of his *Opuſcula*. But he very properly remarks, that ſome of theſe waters have, amongſt their component parts, ſome ſubſtances, as *chalk* and *gypſum*, which by no means can be wholſome, when taken internally. From hence appears the reaſon why it ſometimes happens, that ſeveral patients find their conſtitutions hurt after the uſe of ſuch waters, although their particular complaints have been effectually cured. It is upon this principle, this great Philoſopher founds his opinion, viz. that artificial mineral waters are, and muſt be, more beneficial than natural ones; provided they be properly imitated, by employing only thoſe conſtituent parts in their compoſition, which may produce a ſalutary effect, and not introducing any of noxious qualities.

The good effects produced by theſe artificial waters have been demonſtrated in numerous caſes, and confirmed by the moſt irrefragable and reſpectable teſtimonies, and by the general uſe now made of them in Sweden; for which I refer the reader to the ſaid *Opuſcula* of Profeſſor Bergman, where he treats of this ſubject, more particularly in § 19 of his Treatiſe *de Aquis medicatis frigidis arte parandis*.

26. All mineral waters may be divided into two or three claſſes, viz. thoſe which come from their ſprings almoſt as cold as the temperature of the atmoſphere; and thoſe which ariſe from the earth with a conſiderable degree of heat, ſome being as hot even as boiling water. The firſt kind are almoſt all (and perhaps all, without exception) impregnated with *fixed air*, which is the principal menſtruum, by which the other ſubſtances therein contained are properly diſſolved, according to the nature of the reſpective meanders, or ſubterraneous canals, they paſs through in the bowels of the earth. In order to imitate theſe, nothing elſe is neceſſary but to impregnate them with *fixed air*, as has been ſhewn in the preceeding pages, and to add the reſpective ſubſtances already known by the analyſis of each kind,

withholding thoſe whoſe obnoxious qualities may rather injure than relieve the patients.

27. The proceſs is ſimply as follows: take a ſmall glaſs or two, like that repreſented by fig. 23, but rather ſhort, and as wide as the neck z z, fig. 1, will admit of: this muſt have a hole on it's ſide, in order to be put in and taken out of the veſſel B of the machine, by a crooked piece of iron-wire. The reſpective ſubſtances belonging to each kind of mineral waters are put in this glaſs in due proportion to the quantity of water in the machine. It is let down into B: the chalk and vitriolic acid are put into the under veſſel A, &c. as directed in No. 8, and following: and the whole is to be left to work by itſelf one night, or ſix or ſeven hours in the day-time, in a cold cloſet. By this method the water will be fully impregnated, and prepared for uſe. The following are the mineral waters more generally known, as far as I can judge, in this country, amongſt thoſe whoſe analyſis Profeſſor Bergman mentions in his ſaid *Opuſcula*. But the reader may eaſily make any other kind of *artificial mineral* waters, by this eaſy and ſure method; provided he can get a good analyſis of each, and obſerves the exact proportion of the ingredients to the quantity of water. In the following preſcrip-

tion,

tions, I ſuppoſe, the kanne or *cantharus* of Sweden, to contain *five pints and an half* Engliſh wine-meaſure *(k)*; but as to grain weights, they are found, on compariſon, to be nearly alike, 1000 Engliſh grains making but 1047 Swediſh.

28. *To make the true* PYRMONT WATER.

To every pint of pure common water in the veſſel B of fig. 1, add the following ingredients, viz.

9 gr. of crude (uncalcined) magneſia alba,
5 gr. of Epſom ſalt,
2 gr. of common ſalt,
And two or three plates of ſoft ſteel or iron, filed clean from ruſt, in the glaſs, fig. 23.

(k) Mr. Paucton (in his *Metrologie*, printed at Paris in 4to, 1780) ſays, that the Engliſh gallon contains 4 pints of Paris, viz. 192 cubic french inches; and the Swediſh kanne only 132 of the ſame: from whence it appears, that our pint (= 24 cubic french inches) is therein contained 5 ½ times. As to the weights, he ſays, the Swediſh apothecary's pound is to the Engliſh Troy pound, as 7284 to 7618, (or 7416 to 7756): but the proportion given in the Memoirs of the Royal Academy of Stolkholm, for 1772, p. 330, between the Swediſh and Engliſh pound of apothecary's weight is, as 7416 to 7766: and this ſhews, that 1000 Engliſh grains are equal to 1047 of the Swediſh weight.

There ſhould be a ſmall hole in the glaſs, fig. 23, to take it with the plates out of B, when the proceſs is finiſhed, by means of the crooked iron-wire mentioned No. 27; leſt they ſhould contract ruſt, and damage the valve, as mentioned No. 18.

29. *For making the* SPA WATER.

To each pint of water in the ſame veſſel B, fig. 1, add the following, viz.
4 gr. of uncalcined magneſia.
2 gr. of mineral alkali, or *ſal ſodæ.*
1 gr. of common ſalt.
And 2 or 3 pieces of ſoft ſteel in the glaſs fig. 23, within the veſſel B, as in the preceding article.

30. *For making the* SELTZER WATER.

To each pint of water in the ſaid veſſel B, fig. 1, add the following, viz.
6 gr. of uncalcined magneſia alba,
5 gr. of mineral alkali, or *ſal ſodæ.*
22 gr. of common ſalt.

31. *For making the* SEYDSCHUTZ WATER.

To each pint of water in the ſaid veſſel B, fig. 1, add the following, viz.
3 gr. of uncalcined magneſia alba,

ʒ ij ſs (150 or 156 gr.) of Epſom ſalt,
5 gr. of muriatic magneſia (*l*).

32. *For making* ARTIFICIAL WATERS, *like thoſe of* AIX-LA-CHAPELLE.

Impregnate the water with *fixed air*, as directed in No. 8: certainly this operation may be ſaid to be abſolutely neceſſary.

Then throw into the veſſel A, any quantity (ſuppoſe a drachm or two) of powdered *liver of ſulphur* (*m*), with vitriolic acid,

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(*l*) *Muriatic Magneſia* is prepared by throwing little by little crude or uncalcined Magneſia into one or two ounces of marine acid, until it is ſaturated; which it will be, when a bit of blue paper, tinged with lithmus, does not become of a reddiſh colour, if dipped in the ſolution. This being filtred, and dried on the fire, muſt be kept cloſe in a glaſs phial, with a ground ſtopple; otherwiſe it will deliqueſce by the moiſture of the atmoſphere.

(*m*) *Liver of Sulphur* is commonly to be had, ready prepared, at the chemiſts and apothecaries ſhops: or may eaſily be made by mixing equal parts of mineral alkali, and brimſtone in powder, in a crucible, or in an earthen veſſel not glazed, over a gentle fire, ſtirring them with a ſtick, till they are united together into a brown reddiſh maſs: throw it on a ſtone greaſed with oil; break it to pieces immediately, and keep it in a glaſs veſſel with a ground ſtopple. But a mixture made in the ſame manner, over a gentle fire, of three parts of clean filings of iron, with two of brimſtone, is to be preferred, for the preſent proceſs. See Bergman's *Opuſcula*, vol. I. p. 242.

which will produce ſome *ſulphureous air*, with which the water in the veſſel B, will be ſtrongly impregnated in a few hours. Afterwards put to each pint of water, the following, viz.

6 gr. of common ſalt,

14 gr. of mineral alkali, or *ſal ſodæ*, which will ſoon diſſolve, and the water may be drank immediately.

But the beſt way is to make no more at once, than is intended for immediate uſe; as, for inſtance, 2 grains of common ſalt, and 5 of mineral alkali; if one third part of a pint is to be drank at each time: and this is to be done a little before the water is drank.

33. As to the making *Hot Mineral Waters*, it is certain, that they may equally as well be made at home, with the greateſt perfection; even much more beneficial than the natural ones, for the very complaints in which their efficacy is already aſcertained. The ſame learned profeſſor, Bergman, gives the beſt analyſis of ſome cold and hot mineral waters of the hepatic kind, in the above precious Treatiſes, where he ſhews at the ſame time, the moſt accurate and rational method of making a proper analyſis of every other ſpecies of mineral waters. He there mentions the method for boiling this water, without evaporat-

ing its *aerial acid* or *fixed air*. The moſt effectual is putting it in a cloſe metallic veſſel; and I think one of iron to be the fitteſt for medical operations, if proper care is taken to prevent its ruſting. This veſſel is ſimilar to the known *Papin's Digeſter*: and it muſt be furniſhed with a cock on it's cover, both to let out and to examine the contents at pleaſure, *&c.* But this being a new branch of medical knowledge, which I am not qualified to purſue, I heartily wiſh, that ſome young phyſician, endued with talents equal to the taſk, and actuated by a warm zeal for the benefit of mankind, ſhould apply himſelf to this new branch of the medical profeſſion; in which, no doubt, he will meet with all the encouragement, he may have a right to expect, from the generoſity and gratitude of the Public.

On EUDIOMETERS.

34. The happy diſcovery you have made for the general benefit of mankind, and perhaps of almoſt the whole animal creation of this globe, by finding that *nitrous air is a true teſt of the purity of reſpirable air*, which is abſolutely neceſſary to life, and without which it is preſently extinct, gives a moſt ſtriking inſtance of the blameable ſlowneſs of mankind to pay a proper attention to thoſe objects, the importance of which is infinitely ſuperior to

that of the numerous trifling novelties, which ſo often ſpread, with prodigious rapidity, through remote provinces, and even to the moſt diſtant countries of the Earth. Since the beginning of the year 1772, in which you announced this moſt intereſting and valuable diſcovery, in the 62d vol. of the *Philoſophical Tranſactions*, no more than three or four philoſophers, that I know of, have given any conſiderable degree of attention to ſo important a ſubject; I muſt acknowledge, however, that ſince the firſt edition of this pamphlet, their number is very conſiderably increaſed *(n)*.

35. The

(n) Mr. Volta, Profeſſor of Natural Philoſophy at Pavia in Italy, has made a diſcovery, mentioned No. V, of the Appendix to your third volume *On different Kinds of Air*, which ſeems cloſely connected with the preſent ſubject. He diſcovered, that *inflammable air* is contained in the mud of almoſt all lakes, marſhes, and wet grounds of Italy; and he publiſhed different Letters on this ſubject, of which he was ſo kind as to ſend me a printed copy, after part of this letter was printed. The experiments you have made afterwards with me at Calne on this matter, ſhow that this air is leſs inflammable than what proceeds from the ſolution of metals, with vitriolic acid; it burns with a lambent flame, like the air produced by heat from charcoal: but the inflammable principle of this air ſeems to be much denſer; as it bears a larger mixture of common air, without deſtroying the power of being inflamed. This diſcovery of Profeſſor Volta accounts very well for the unhealthy habitations ſuch marſhy grounds generally afford to the human ſpecies: and ſhows the neceſſity of examin-

35. The Chevalier Landriani, and the Abbé Fontana, both of Italy, and already known to the public by their philoſophical labours, were the firſt, as it ſeems, who availed themſelves of this diſcovery: and both propoſed to the public, a kind of the moſt uſeful inſtruments, that we can boaſt of, among the numberleſs ones already employed in philoſophical reſearches and experiments. They gave to theſe inſtruments different forms, in their conſtructions, which are more or leſs liable to conſiderable objections, as appears by the printed deſcriptions that each of them has ſeparately

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examining, with care, by means of the Eudiometer, what places are fit for being inhabited. This is a new and a very intereſting requiſite, never to be overlooked, before any building is erected, or the place for any country ſeat is fixed upon. Such grounds or places, whoſe atmoſphere is loaded with phlogiſtic miaſms, are the moſt dangerous to animal life: becauſe the air of ſuch an atmoſphere cannot be a good conductor or diſcharger of the ſuperabundant phlogiſton, of which the animal œconomy requires to be unloaded: this being the aim intended by Nature in the function of reſpiration, as you have at laſt diſcovered, and incontrovertibly demonſtrated, by the moſt deciſive experiments, to be the caſe; after ſo many ineffectual attempts of the greateſt philoſophers of all ages. This appears by ſection V. page 55, and the following, of your third volume *On different Kinds of Air*, London edit. 1777; and by *Phil. Tranſact.* vol. LXVI. p. 226.

paratelypubliſhed : and the Chevalier Landriani has tranſmitted to England, as a preſent to you, the very inſtrument he had made uſe of, to eſtimate the reſpective ſalubrity of the air in different parts of Italy, as mentioned page xxiii. of the Preface to your third volume *On different Kinds of Air*. This Eudiometer is ſmaller than that deſcribed by him, and publiſhed in the ſecond volume of *Journal de Phyſique* for the year 1775, though nearly of the ſame form. It conſiſts of a glaſs tube, ground to a cylindrical veſſel, with two glaſs cocks, and a ſmall baſon, all fitted in a wooden frame. Quickſilver is there uſed inſtead of water; and that part of it which replaces the bulk loſt by the diminution of the two mixed airs, is conducted either through a a kind of glaſs ſiphon, or through the capillary holes of a glaſs funnel: ſo that by its fall, the whole mixture of the two kinds of air is more readily made.

36. Dr. Falconer of Bath ſent, ſome time ago, to the Royal Society of London, a glaſs tube, neatly divided; by means of which, one may be enabled to know the quantity of the diminution produced in a certain bulk of the mixture of *nitrous air* with another air, in order to judge of its ſalubrity, which you have

ſhewn

ſhewn to be in proportion to the *diminution in the ſum of their original bulk, after they are mixed together.* This method is the neareſt to your original one, or rather is the very ſame you have uſed in the beginning of this diſcovery; as appears by your printed work on this ſubject: and I think it to be the readieſt of all, whenever no great nicety is required in obſervations of this kind. There are, however, ſo many circumſtances neceſſary in a good inſtrument for fully anſwering ſo great an object to its utmoſt extent, that I ſhould be deterred from offering to the public what I have as yet done on this ſubject, was I not aware, that ſome advantages always accrue to public good, by any new ſteps towards perfection, how diſtant ſoever we may ſtill happen to be from its compleat attainment.

DESCRIPTION OF THE FIRST NEW EUDIOMETER.

37. Of the three Eudiometers I have contrived, which are repreſented fig. 8, 15, and 16, in the annexed plate, I think the laſt is the eaſieſt in its application, and the moſt exact in its reſults. The figures 12, 14, 16, and 17, repreſent it in different poſitions, for the better underſtanding of its application: and it con-

ſiſts of the following parts, *viz.* a glaſs tube *m n e d*, fig. 16, about twelve or fifteen inches long, and of an equal diameter, with a ground glaſs ſtopple, *m*: a veſſel, *c*, the neck of which is ground air tight to the lower end *d* of the tube: and two equal phials, *a* and *b*, whoſe necks are alſo ground air-tight to the reſpective mouths of the veſſel *c*. Both theſe veſſels contain nearly as much as the whole tube *m n e d*.

38. There is, moreover, a ſliding braſs-ring, marked *z*, which ſlides in the tube *n d*, and may be made tight at pleaſure by a finger-ſcrew: and, laſtly, a ruler, either of braſs or of wood, repreſented fig. 11, which is divided into equal parts, and indicates the contents of both the phials, *a* and *b*, when thrown into the tube, by the number of parts which is engraved or ſtamped about the middle of it. The two bent pieces of braſs *z t* ſerve to hold it eaſily in the ſide of the tube *n d*, fig. 14 and 17, keeping it cloſe to its neck *n*, by the notch *i*.

39. I have lately contrived theſe inſtruments with braſs-necks, cemented to each piece, inſtead of the glaſs ones, ground to one another: and I find ſeveral advantages in this improvement. Becauſe the ſtem or tube *n d*,

may be made more regular, *viz.* with a more uniform bore, ſo that equal quantities of the fluid put in it's inſide, are there meaſured by equal parts of it's length: and, at the ſame time, a ſecond tube, more than two feet long, may be fitted to the part *c* of the ſame Eudiometer, for making experiments with dephlogiſticated air, *&c.* Beſides this, the turning of the veſſel *c* is eaſier and ſafer, than when the necks of glaſs are ground to one another: as they are apt to crack, when too tight; and often fall down, if too looſe, ſo that the proceſs muſt then be repeated from the beginning.

40. Experiments with theſe Eudiometers, which are eaſily conſtructed, may be made either with water or with quickſilver; with this difference, that when the laſt is made uſe of, the Eudiometers (particularly the third, repreſented fig. 8, which ſeems the fitteſt for being uſed with quickſilver) will be more convenient, if made of a ſtill ſmaller ſize. Mercury, however, is a fluid that, I think, never ought to be uſed preferably to water, in the inſide of Eudiometers; becauſe it ſuffers a ſenſible action from the contact with *nitrous air*, as yourſelf have obſerved: and this muſt have an influence on the reſults of the experiments. Water, on the contrary, ſeems leſs

liable to miſtakes, although it imbibes ſome part of the *nitrous air*. In fact, this effect only takes place in a long time, or with much agitation. After duly weighing the queſtion on both ſides, I certainly think water may be generally uſed, without the fear of any ſenſible error. The weight and the dearneſs of quickſilver are, likewiſe, two other conſiderations to give the preference to water in theſe experiments.

THE PROCESS.

41. In the firſt place there muſt be either a trough, as repreſented fig. 17 (*o*); or at leaſt a com-

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(*o*) This figure repreſents the proper ſhape a trough ſhould have for any experiments on different kinds of air. It is made with ſtrait boards of elm-wood *one inch* thick. The inſide dimenſions are 25 inches long, 13 ½ wide, and 11 deep,] Engliſh meaſure. The two end-boards, *c d* and *e f*, are fitted into a groove, cut in the other three boards; this is daubed with thick white paint, as a cement, to keep the water well in: and the whole is faſtened with ſcrews from the outſide. The ſhelf *w a n o* is eight inches wide, and two inches thick. It has three holes of three tenths of an inch diameter, with as many ſeparate cavities underneath, ſo as to ſerve like ſo many funnels. The figure, however, repreſents a glaſs funnel *t* cemented to the middle hole *n*: which is equally convenient. This ſhelf is ſupported by four metallic hooks *z z V w*, which may be raiſed or lowered at pleaſure, by the wooden wedges there repreſented: and it is white painted a common tub nearly filled up with water: unleſs the tall glaſs receiver, of which I ſhall ſpeak No. 54, be at hand. I take out the ſtopple *m* (fig. 16), and fill the Eudiometer entirely with water, keeping it in the poſition repreſented fig. 16 and 17. I then ſhut it with the ſtopple *m*, and put the lower part *c*, under the ſurface of the water in the tub (fig. 17) in an erect poſition, as it is therein ſeen. But if the tub *d c e f* (fig. 17) is large enough, I dip at once the whole inſtrument, without its ſtopple and phials, under the water; and ſhut it up with the ſtopple *m*; then I put it in an erect poſition, keeping only the lower part under the ſurface of the water. This being done one way or other, I take the phial *a*, filled with water; and keeping its mouth downwards under the ſurface of the water, I fill it with that air, the ſalubrity of which I want to aſcertain. This is done, either by putting the phial *a* on the ſhelf *n o* of the tub, fig. 17, and throwing the air into the glaſs funnel *t*, which is there cemented to the ſhelf; or by holding in the

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painted with oil colour, as well as the whole trough, both in the inſide and outſide. However, I have ſince ſeven or eight years ago, a trough of an oval form, made by a cooper, with a ſimilar ſhelf, ſupported by three wooden pegs in the inſide, which has been as ſerviceable to me, as any of a much greater expence.

left hand the ſame phial *a*, together with the glaſs funnel *B* (which is repreſented fig. 18, and has no pipe at all) applied to the mouth of the phial, whilſt I throw up the air, with my right-hand, into it *(p)*.

42. But leſt the heat of my hand ſhould produce any conſiderable expanſion in this air, I have uſed, in hot weather, the wooden tongs repreſented fig. 21, with two bent wires *x x*, in order to hold the glaſs funnel *z* cloſe

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(p) The caſe I am ſpeaking of, is, when I have a bottle of air, which has been taken at any diſtant place, and ſent for trial. If a glaſs bottle, with a ground glaſs ſtopple, is filled with water or with mercury, and emptied in the place whoſe atmoſpherical air is intended for being examined, it will, of courſe, be filled with that air: and, being cloſely ſhut with the glaſs ſtopple, may be carried to any diſtant place for trial. By this means the atmoſpherical air of any part of a country, may be ſent to any diſtant one, in order to aſcertain its comparative ſalubrity: and many uſeful inquiries and diſcoveries may be made hereafter on this ſubject, with great eaſe, and at very ſmall expence.

But if I only want to try the air of the room where I have the Eudiometer, I then only pour out, of the phial *a*, the water it contains. I find, however, that, after ſome trials with *nitrous air*, the atmoſphere about me is loaded with phlogiſtic miaſms: and, for that reaſon, I I always empty the phial *a* out of the window of the room, in order to have nearly the ſame kind of air in all the experiments.

cloſe to the mouth of the phials; but when the phials are made with wide baſes or bottoms, as repreſented in the plate, they are handled by the ſame, without the leaſt inconvenience.

N.B. Particular care muſt be taken that each phial be *exactly* filled with air, viz. neither with a greater or leſs quantity of air than what is equal to its contents *(q)*.

(q) There are ſome niceties to be obſerved in order to fill up, exactly, any phial intended to ſerve as a meaſure of air; of which I muſt give an account in this place. The eaſieſt method to ſucceed is the following: Let a glaſs funnel *t* (fig. 17), be cemented under the hole *n* of the ſhelf *n o* in the trough. In this caſe, I hold the phial *a*, filled with water, with its mouth downwards, over the hole *n* of the funnel *t*: I throw the air into the funnel, and, when the phial is filled with air, *I take it ſideways, rubbing its mouth along the ſurface of the ſhelf, ſo that the redundant air, adhering to the mouth of the phial, be got off*: and I put it into the mouth of the Eudiometer it belongs to. But as the heat of the hand muſt expand the air contained in the phial, which of courſe will then contain leſs air than its real meaſure, when in the temperature of the ſurrounding water; I handle the phial with a kind of pliers or tongs of wood, repreſented fig. 21, till the neck enters into the proper place of the veſſel *c*, where I ſecure it with the other hand; and, laying aſide the wooden tongs, I make it properly tight. But if the phials have a wide foot or baſis at their bottoms, as repreſented in the plate; it will then be enough to handle them

43. The phial *a* being properly filled with that air, the ſalubrity of which I am to examine; I put it into the mouth of the veſſel *c*, making it rather tight, which muſt be done with ſome care; for, if the phials *a* and *b* are not tight enough to the reſpective mouths of the

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them by it only: ſince the heat of the hand cannot be then communicated, in ſo ſhort a time, to the air in the inſide, through ſuch a ſolid and wide baſe.

If I have not the convenience of a trough, furniſhed with a ſhelf, as abovementioned: an aſſiſtant holds the funnel under the water in a common tub, whilſt I fill up the phial with air: and I take care to hold the phial in ſuch a manner, that the end of the funnel be out of the inſide of the phial in the laſt moment, that the air may ruſh out, after it is totally filled: otherwiſe that part of the phial, occupied by the end of the funnel, will not be totally filled with the air. But as the air will then make a kind of a pouch in the mouth of the phial; by ſimply *rubbing it ſideways on the bottom of the tub*, the redundant air will go off, and the real quantity anſwering to the capacity of the phial, will be left within.

Even without any aſſiſtant, but with a little care, a perſon may hold both the phial and the funnel in the left hand, whilſt he throws the air into it with the other hand; as I have myſelf frequently done in experiments of this kind. But, if I make uſe of the wooden tongs, I add to them two bent pieces of wire *x x*, (fig. 28.) by means of which the funnel is kept cloſe to the mouth of the phial.

N.B. Since the firſt publication of this letter, I have entirely left off the uſe of theſe wooden tongs, as not eſſentially neceſſary.

veſſel *c*, they will ſlip out, when turned downwards: and, if too tight, the veſſel *c* may eaſily crack, and become unfit for uſe. The better to avoid theſe accidents, and to judge of the proper degree of tightneſs, the necks of the phials *a* and *b*, and of the veſſel *c*, as well as the glaſs ſtopple *m*, are to be rubbed with tallow, previouſly to every experiment. When I have done with the phial *a*, I take the other phial *b*, filled with water: by the ſame method I throw into it ſo much *nitrous air*, as to be perfectly filled up with it: and I then replace this phial *b* in the other mouth of the veſſel *c* (*r*). This being

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(*r*) No pains or trouble ought to be ſpared, in order to obtain at any rate, a *nitrous air* perfectly alike in its contractive power, when mixed with common air.

In order to come the neareſt to this, I take a phial *D* (fig. 19.) like thoſe you have deſcribed in the ſecond volume of your works *On different Kinds of Air*: to the mouth of which is ground air-tight the crooked tube *n z* in the ſhape of an S. I fill the half of this phial with thin braſs wire, cut by a pin-maker to it's proper length: I then fill three quarters of the phial with common water; and the remainder with *nitrous acid*, which I have always taken of the beſt ſort, at Apothecaries' Hall in London. I put the crooked tube *n z* to the phial; and, as ſoon as the efferveuſcence cauſes the liquor to riſe to the end *z* of the tube, I paſs it under water into the mouth of the bottle *E* (fig. 20.) which is filled with water, and inverted with it's mouth downwards, as marked being done, I take off the ſtopple *m*, in order to eaſe the ſeparating both phials in the following operation.

44. I

by F, fig. 17. upon the hole of the ſhelf *n o*, which muſt always be covered with water within the trough, or pan, as ſeen fig. 17.

When the bottle *F* is entirely filled by the *nitrous air*, I ſhut it up with its ſtopple *x* (fig. 20,) which I paſs under the ſurface of the water, to prevent any communicution with the external air: and I puſh this bottle under the ſhelf, where I let it remain for a quarter of an hour, to acquire the ſame temperature with the ſurrounding water: and the ſame I always obſerve with the bottle, containing that atmoſpherical air, which I deſire to try, before I put it into the phial *b*.

I muſt acknowledge, however, that, notwithſtanding theſe precautions, I cannot ſay that all the reſults of my experiments, even when made upon the ſame atmoſpherical air, have as yet agreed ſo exactly as I flattered myſelf they would: not only myſelf, but even Dr. Prieſtley, and all fair experimenters, have found the ſame. *See No.* 75. Perhaps there is ſome difference in the ſtrength of the *nitrous air*, the denſity of which I thought might be proportionable to its ſtrength; if ſo, it may be brought to a ſettled ſtandard, and be determined by means of a glaſs hydrometer. Perhaps there is ſome other little variety in the circumſtances of the experiments, the influence of which I am not aware of. But let it be as it may: I very willingly leave this problem to be reſolved by abler philoſophers than I can pretend to be: and I heartily wiſh they may ſucceed better than I have done: for, without being aſſured of getting every where a certain *ſtandard*

nitrous

44. I afterwards take the Eudiometer with my left hand, and holding it by the part *d*, I keep

nitrous air, by which the ſame atmoſpherical air may be equally affected, we cannot draw with certainty any general deciſive concluſions, from Eudiometrical experiments made in diſtant times or places.

Before I leave this ſubject, I cannot help mentioning two ſtriking circumſtances relating to *nitrous air*. The firſt is the great quantity of it, produced by the action of *nitrous acid* on many metals; which may ſtill be carried to a greater extent, if helped, by approaching the flame of a candle to the bottom of the phial, which contains the ſolution, when it ſeems to be nearly done with: if the bottom of this glaſs phial, fig. 19, be round and very thin, it will not crack by the heat of the flame. The ſecond circumſtance is the antiſeptic power of *nitrous air* to preſerve animal matters from corruption. A beef-ſteak, almoſt entirely putrid, and with an inſupportable ſtench, being put into a jar of *nitrous air*, in leſs than two days, was perfectly reſtored, and very eatable when dreſſed. A pigeon was very well preſerved above ſix weeks, by the ſame treatment; and, when roaſted, was found good enough to be eaten, without any conſiderable diſlike. Two other pigeons were kept in it full ſix months, without corruption: they were ſtill very firm, and of a good colour: but the fleſh had loſt all its flavour, and was far from being eatable, when dreſſed. But the *nitrous air* for theſe œconomical purpoſes, which may be of a great reſource at ſea, as well as at home, muſt be made out of *nitrous acid* with iron, or other metal leſs exceptionable than braſs or copper, the effluvia of which are pernicious to animals: and for this reaſon, the

I keep always the part *c* under the ſurface of the water in the trough; both to avoid breaking any of the phials, if it chances to fall, and that no bubble of external air may ruſh in. Then I turn with the right hand the veſſel *c* upwards, ſo that the two phials may be downwards, as repreſented fig. 14. By this operation, the two kinds of air come up to *x*, from the phials *a b:* and there they mix together in the beſt poſſible manner, the particles of each having a large room to come into contact with each other; ſince the foremoſt ones do not detain thoſe which are behind, as it happens when this mixture is made in a narrow veſſel. *See No.* 76.

45. This being done, I obſerve the fall of the column of water in the tub *n d*, which follows the contraction or decreaſe of the bulk of mixed air in *x*. But there is before that time a conſiderable expanſion in the very firſt moment of their coming in contact, owing to the *ſenſible heat* produced thereby. *(See my Eſſay on Elementary Fire, No.* 416 *B, in French.)* I obſerve, I ſay, the fall of the column of water within the tube *n d*, till the inſtant that it appears almoſt ſtationary, which

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method already mentioned, No. 23, ſeems to deſerve ſome particular regard, whenever the circumſtances allow it to be made uſe of.

will happen in a few ſeconds, and will be eaſily obſerved by means of the braſs-ring z *(s)*, being puſhed forwards by little and little, according as the inſide ſurface of the water falls in *n d*.

N.B. That the two airs may mix the better in *x*, I ſhake the veſſel *c* gently, about half a dozen times.

46. As ſoon as the diminution of the mixed air appears to be ſtationary in *n d*, I fill up the tube with water; and then ſhut it up with the ſtopple *m*, taking care not to leave any bubble of air within; and immediately incline the top of the inſtrument forwards, till the air comes from *x* (fig. 14.) up to the top *n* of the tube. I keep the lower part of the inſtrument dipped in the water of the trough: take off the veſſel *c*, with its phials *a b*: *and raiſe or lower the tube of the Ediometer, in an erect or vertical poſition, ſo as to*

(s) This braſs-ring z has a double advantage, viz. that of being uſed as a mark to aſcertain eaſily the ſeeming ſtationary point of the diminiſhed bulk of the mixed air in *x*, by the ſurface of the water in *n d*; but it's moſt important uſe is, the avoiding thereby the parallax of the viſual ray from the ſame ſurface of water in the tube *n d*, which is the ſame as I have ſpoken of in the French Treatiſe upon my New Barometers, No. 204 and 206.

ſee the ſurface of the water, in the inſide, even with that on the outſide; which I mark, by ſliding the braſs-ring *z*, and fixing it there by it's finger-ſcrew; and afterwards I meaſure it's diſtance from the top *n*, by applying the divided ſcale (fig. 11.) to it's ſide, exactly over the notch marked in the neck *n* of the tube. Otherwiſe I apply the ſame ruler (fig. 11, without making now any uſe of the braſs-ring *z*) to the ſide of the Eudiometer, whilſt it is immerſed in the water of the trough: and there I ſee the true dimenſion of the remaining bulk of the mixed airs.

N.B. Some water from the trough ſhould be thrown four or ſix times over the tube *n d*, before the meaſure is taken; in order to bring the air within the tube to the ſame temperature with the water.

47. Perhaps the beſt method for theſe obſervations, would be to allow time enough for the mixed air to ſettle to a certain bulk; but this ſometimes requires a whole day and night. I leave, however, the choice of theſe two methods to the obſerver, who may uſe both, if he pleaſes, provided he keeps diſtinctly the reſult of each method, in his account of theſe experiments. In all probability, the firſt method of meaſuring the diminiſhed bulk of the mixed air, as ſoon as it appears ſtationary,

is what philoſophical obſervers will make uſe of, as the moſt expeditious. But I muſt recommend to them the greateſt care in making every experiment intirely ſimilar to each other in all their circumſtances; becauſe, without this particular attention, no comparative reſults can ever be had in any kind of experiments whatſoever *(t)*.

48. No doubt but the reſults of ſuch ſimilar experiments will be very nearly alike: and by taking a medium of them all, which muſt be repeated at leaſt three or four times upon each kind of air (*viz.* by dividing the ſum of their reſults by their number. See No. 73.) This mean reſult will be ſuch as we may depend upon, to draw proper inferences relative

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(t) This is a general rule, which hardly needs to be mentioned, even to beginners in Experimental Philoſophy. Nevertheleſs (to the glory of the preſent century!) a mighty philoſopher was at laſt lucky enough to unravel this abſtruſe and myſterious *Rule of Uniformity* in aerial atchievements; and by means of this happy diſcovery, he was enabled to ſtrike out the *wonderful new Method* of performing eudiometrical experiments, with no greater variation than the 50th part of one meaſure of air. See Mr. *Cavallo's* Treatiſe on the *Nature and Properties of Air*, p. 328; and No. 74, and following, of this Letter.

(u) I

tive to the comparative qualities of each air *(u)*.

N.B. Proper caution muſt be uſed to clean very carefully the inſide ſurfaces of the tube *n d*, and of the meaſuring phials *a* and *b*; or elſe there may happen ſome errors in the experiments. See No. 83. And alſo not to let any bubble of air to ſtick to the necks of the veſſel *c*, or of the tube at *d*, *&c.*

49. The number marked about the middle of this ruler (fig. 11); as, for inſtance, * * = 96 means, that the contents of both phials *a* and *b*, are equal to ninety-ſix diviſions of the ruler, when put into the tube of that Eudiometer: that is to ſay, they are equal to a ſolid cylinder, as thick as the inſide of the glaſs tube, and whoſe length is ninety-ſix diviſions of the ruler, which has been divided into tenths of an Engliſh inch.

50. Now if, for inſtance, this remaining bulk of mixed air correſponds to the 56th

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(u) I do not mean, that, by eudiometrical experiments, we are enabled to diſcover all the bad qualities of the atmoſphere, but only thoſe of it's phlogiſtication. Theſe however, muſt always be of the moſt pernicious kind to animal life; unleſs they happen to be compenſated, or even, overcome, by ſome local circumſtances, which are powerful enough to counteract their noxious influence.

diviſion of the ruler, it ſhews that, out of 96 parts, only 40 (=96—56) have been loſt, or contracted: and, in this caſe, the wholeſomeneſs of that air, which I call A, will be $\frac{40}{96}$. If another equal quantity of a different air, which I ſhall call B, had alſo been tried by the ſame Eudiometer, and its reſiduum was equal to 60 parts of the ſame ruler, the reſpective ſalubrity of the air *B* will then be to that of the air A, as 36 (=96—60) to 40.

51. But, if the air *B* had been tried by another Eudiometer, whoſe proportional dimenſions, marked about the middle of the ruler, were * * = 108, then the reſpective ſalubrity of theſe two kinds of air *A* and *B*, would be in the compound ratio of $\frac{36}{108}$ to $\frac{40}{96}$

$$= \frac{36 \times 96 \text{ to } 40 \times 108}{108 \times 96} = 3456 \text{ to } 4320 = 54 \text{ to}$$

67, 5: that is to ſay, the wholeſomeneſs of the air *B* would be to that of the air *A*, as 54 to 67 $\frac{1}{2}$ (*v*).

(*v*) It is ſuppoſed, that the inſide of the tube is of an uniform diameter; but it often happens, that there are ſome varieties in different parts of its whole length. When they are not very conſiderable, we may neglect their influence in the reſult of theſe eudiometrical experiments; but, when the contrary happens, it will be very eaſy to make a proper allowance for them in the calculation. It is for this reaſon, that I have always di-

52. Nearly the ſame reſults would be found, if the ruler (fig. 11) was applied to the ſide of the Eudiometer as ſoon as the incloſed mixture of air comes to it's utmoſt diminution, as mentioned No. 45: becauſe as much water muſt fall in the tube *n d*, as correſponds to the diminution ſuffered by the two mixed airs in *x* (fig. 14). But the preſſure of the different columns of water on the air in *x*, muſt cauſe ſome varieties in it's bulk: and theſe varieties ought not to be overlooked in nice experiments. Theſe are, however, totally avoided by the proceſs alreaſty deſcribed No.

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rected, that the contents of one ſingle phial be marked alſo upon the ſcale of each Eudiometer, as well as the contents of both phials: For inſtance, as in this manner:

* * = 96
* = 47

which means, firſt, that the contents of both phials *a* and *b* are equal to a cylinder, whoſe diameter is the ſame as that of the inſide bore of the tube *n d* (fig. 16), and whoſe height is equal to 96 equal diviſions of the ruler: ſecondly, that the contents of a ſingle phial are equal to 47 diviſions in the upper part of the ſame tube *m n d*, and of courſe to 49 diviſions (=96—47) of its lower part. By this difference it appears, that the tube of ſuch Eudiometer is wider in the top than at the bottom, by $\frac{2}{96}$ of the whole: and an allowance may then be made, by the *Rule of Proportion*, to correct this difference; according as the place of the inſide ſurface of water in the tube, ſtands under or above the 47th diviſion of the ſcale, &c.

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46, and marked by Italics in this new edition, that the reader may not overlook them as happened already to a modern writer. See No. 64. But this proceſs is not eaſily performed, when the tube of the Eudiometer is of the longer ſort, for the purpoſes hinted in No. 92 : as a greater depth of water is then required to bring the inſide ſurface in the tube $n\,d$, even with that of the trough. In this caſe, recourſe may be had to calculation, according to the Problem 19, No. 99 of Chr. Wolf's *Aerometria*, in order to find the real quantity of the diminiſhed air contained in $n\,d$. This requires that the height of the Barometer be known alſo at that moment.

53. Let us call the height of the barometer m, which I will ſuppoſe to ſtand at 28 inches. The inſide ſpace from n to e (fig. 16.) I will call a (=39 inches): and the difference of the two ſurfaces $z\,e$ I will call n (= 14 inches): then the formula $m : m-n :: a-n : x$, will give the real quantity of the diminiſhed air in $m\,z$, if the two ſurfaces were even, viz. $28 : 28-14$ (=14 inches) $:: 39-14$ (=25) $: x$: from whence we have $\frac{14 \times 25}{28} = 12,5$. So that, if the experiment was tried with quickſilver, the quantity of the apparent bulk of

25 inches, ſhould be no more than 12 inches and *an half*. But, as water is 14 times lighter than quickſilver, the firſt term m, muſt be multiplied by 14: and the proportion, in this caſe, will be m $(=14\times28=392)$: $m - n$ $(=392-14=378)$: : 25 : x ; which gives $\frac{378\times25}{392}=\frac{9450}{392}=24,107$; that is to ſay, the bulk of the 25 inches of air, in that caſe, is but 24 *inches* and 107 *milleſimals* of an inch. In order to be the more accurate in theſe calculations, the true ſpecific weight of the quickſilver, relatively to the water employed in the trough, ſhould be known; becauſe it is only when compared with diſtilled water, that quickſilver is nearly *fourteen times* heavier: the difference of temperature between the air of the atmoſphere where the trials are made, and that where the barometer is ſituated, ſhould alſo be known; becauſe a difference, but of a few degrees, will cauſe ſome expanſion in the column of air within the tube *n e*. See No. 63, and following.

54. Whenever I have at hand a tall receiver, like that repreſented fig. 14, the whole proceſs is then more eaſily performed; for, in this caſe, I dip the Eudiometer, inverted as it appears fig. 12, into the water contained in

the veſſel *V S q l:* I then put the two kinds of air into the phials *a* and *b* as aboveſaid, No. 41 and 43: I turn the inſtrument upright, as repreſented fig. 14; and finiſh the proceſs, as I have already deſcribed. It is in this caſe of having a long glaſs receiver, that the column of air is better aſcertained with the lower edge of the ring *z*, which may then be ſeen horizontally in contact with the inner ſurface of the water in the tube, as has been ſaid in Note *s* (*w*).

55. I muſt, however, warn the operator that, unleſs every trial, and even almoſt every part of the proceſs, be made in the ſame temperature; or, at leaſt, unleſs the varieties ariſing from this cauſe be accounted for; no reliance can be had on the reſult of ſuch experiments: it being well known, that air is apt to encreaſe or diminiſh very conſiderably in it's bulk, by the influence of heat and cold. It is for this reaſon, that I conſtantly keep a good thermometer *K*, which hangs by the wire

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(*w*) It was for this very purpoſe, that I have ſometimes taken from the trough the tube *n d* of the Eudiometer, in the laſt operation, by paſſing under it, in the water, a glaſs bell, in which I was then able to make the obſervation, in the manner I have expreſſed; but, in this caſe, care muſt be had, that the air within the tube *n d* does not alter it's temperature.

y r, and is immerſed in the water of the glaſs veſſel, fig. 14, or in the trough fig. 17, whenever I make any of theſe experiments. For the ſame reaſon I take care to leave the Eudiometer and the veſſel of air immerſed in water, time enough, as above mentioned, to get the ſame temperature: and I make uſe of the wooden tongs mentioned in note *g*, whenever I handle the phials *a* and *b* filled with air, unleſs I feel the heat of my hands to be the ſame as that of the water, in the trough, I make uſe of. But if the phials are made with a flat baſis or bottom to each, as repreſented in the plate; in that caſe, the wooden tongs are quite unneceſſary.

EXAMINATION of Mr. CAVALLO's STRICTURES on theſe EUDIOMETERS.

56. The deſcription of my ſecond Eudiometer being here ſuppreſſed, for the reaſons given in the note *(x)*: I ſhall ſubſtitute in it's place, a ſhort examination of a very extraordinary cen-

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(x) In the two preceeding editions of this Letter, I deſcribed in this place, a ſecond Eudiometer, repreſented by fig. 15 * in the plate. This inſtrument had ſome more apparatus, that rendered it dearer, and not ſo ſimple as the other two: and, for theſe two reaſons, I rather choſe to ſuppreſs it in this edition; becauſe ſimplicity in philoſophical experiments, and cheapneſs of the inſtruments

cenſure, which Mr. Cavallo has paſſed on my Eudiometers, in his Treatiſe, publiſhed two years ago, *upon the Nature and Properties of Air:* ſo extraordinary indeed! that it appeared to me, and, I truſt, will ſoon be ſeen in the ſame light by the public, that, had I not been perſuaded that it could not ariſe from any private pique (not being conſcious of ever having given that gentleman the leaſt offence; but, on the contrary, having ever harboured a partial opinion of his abilities) I ſhould have thought it impoſſible to have proceeded from a perſon who had the leaſt inſight into the ſubject: nor can I reconcile it to my feelings, that Mr. Cavallo could have been baſe enough to *ſell his pen* for any profitable emolument, as a reward for eſtabliſhing the credit of Mr. Fontana's Eudiometer, by depreciating mine; which is a ſuſpicion that might perhaps be ſuggeſted by circumſtances, without ever being demonſtrable by direct proofs.

57. Yet, ſince Mr. Cavallo could probably have no other motive in paſſing this opinion, but a conviction of it's being founded in truth; this may be a ſimple error in judgment:

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ments required for their proceſſes, are two of the moſt deſirable circumſtances, *cæteris paribus*, in the inveſtigation of natural phœnomena.

ment: and, I hope, that Mr. Cavallo, as a philoſopher, will not be diſpleaſed to ſee it rectified. I am as liable to deception as he is: infallibility is not the lot of man: but as Mr. Cavallo's criticiſm has already been two years before the public, I will ſubmit alſo to it's deciſion the following obſervations on it.

58. I think it rather odd, that Mr. Cavallo propoſes (p. 315) to give a deſcription of the principal known Eudiometers; *becauſe*, ſays he, *ſome have peculiar advantages, which may be uſeful*—and alſo *becauſe I will not take upon me to determine, which of them is more or leſs uſeful*. He then gives ſcarcely half a page to the account of Dr. Prieſtly's Eudiometer: and not more to that of Mr. Landriani: but employs no leſs than twelve pages in his account of my poor Eudiometers, tranſcribing, word for word, many articles of this letter: and concludes, p. 325, (with what conſiſtency is beſt known to himſelf), by *aſſuring his readers, that all my Eudiometers are quite uſeleſs*. Certainly Mr. Cavallo could as well have cut ſhort the matter in two or three lines (unleſs he intended to enlarge the bulk of his Treatiſe); and palm upon his reader that very *aſſurance* he truſts to. This, however, muſt reſt upon the ſolid grounds of argument and principle, without any regard to

the authority of his aſſertions. Happily theſe are ſo arbitrary, and ſo groundleſs, that they need only to be pointed out to enable the public to judge, both of their inconſiſtency and of their falacy.

59. Mr. Cavallo ſays, p. 326, that the conſtruction of my Eudiometers is principally founded upon the *miſtaken phænomenon* of the increaſe of bulk (*y*) of nitrous and common air, at a certain time after they are put together. Now, if the reader has paid the leaſt attention to the conſtruction of theſe inſtruments, he muſt ſee the falſity of this aſſertion, there being but ſimply the ring *z*, which is employed, only in a particular moment, to obviate that uncertainty; it's pricipal uſe being to avoid the parallax of the viſual ray, in judging of the true height that the ſurface of any fluid really has, within a glaſs tube, when compared with a ſcale placed by it's ſide. See the Note *s* to No. 45. If this ring is,

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(*y*) To avoid any miſtake, the reader ſhould take notice, that this *increaſe of bulk* in the *mixed air*, is not that which always happens in the very moment of the two airs coming together, mentioned No. 45: and which Mr. Cavallo ſeems never to have been aware of; at leaſt, I do not recollect to have ſeen it noticed in the litle part I have read of his voluminous work. The *increaſe* I am now ſpeaking of, is an accidental ſecondary one, which will be explained No. 60, and following.

or is not the *whole*, or the *principal* part of my Eudiometers, any one may judge for himſelf.

60. As to my *miſtaken phænomenon*, which Mr. Cavallo ſays, *is owing he cannot imagine to what cauſe*; the public will eaſily ſee, not only what is the *cauſe* of it, but alſo that it could not have been a *miſtake* of mine, whenever the ſame *cauſe* exiſted, with it's circumſtances. It is true, that I was not able to comply with Mr. Cavallo's requeſt, by ſhewing it to him, at that time he deſired it. I had then loſt ſight of theſe experiments a long while: and was unwilling to ſpend more time to bring them to my recollection. Here is the principle: let the public judge, whether it can fail of producing it's effect.

61. It is well known, that water is always ſome degrees below the temperature of the atmoſphere, when it ſtands in a large quantity by itſelf; unleſs any ſurrounding body is ſo circumſtanced, as to raiſe it to the external temperature. That this is the real fact, every experimenter may try: and this is very eaſily accounted for, by the continual evaporation, which is always more or leſs in water; and which carries off ſo much of it's ſhare of abſolute heat, which it cannot be ſupplied with, from the other bodies in contact with it;

unleſs their contiguous ſurfaces have an equal ratio to the bulk of the water itſelf. If Mr. Cavallo is not aware of this, or is ignorant of it, I cannot help it.

62. Now, when the two airs are brought together in the veſſel *c*, by inverting it; if this veſſel is left under the ſurface of the water in the tub, time enough to acquire the temperature of the water: as ſoon as the mixed airs are brought up to the tube *n d*, this mixture muſt expand itſelf, whilſt it is acquiring the ſame higher temperature of the ſurrounding atmoſphere: but afterwards it decreaſes ſo very ſlowly, that it ſometimes takes above twenty-four hours, as I have ſaid in the words Mr. Cavallo tranſcribed from my Letter, in p. 319 of his book.

63. Add to this; that, if the tub or trough of water is in a diſtant corner of a room, ſhaded from the external heat of the day; and the Eudiometer is carried, as I did carry it often, near to the ſun-ſhine, for the ſake of a better light; this phœnomenon of the expanſion of the mixed airs included therein, muſt be much more conſpicuous. Thus far is ſufficient for the ſuppoſed *miſtake* of that phænomenon, which of courſe is, and muſt be a *real fact*, whenever the ſame circum-

ſtances occur: although, at firſt, I could not find out the true principle or cauſe of it's being ſo; nor, among the many ſolutions I received of this problem, did any hit on it's true cauſe. I have only to add, that on my acquainting my good friend, and true philoſopher, Dr. Prieſtley, with that fact, he anſwered ſome time after, that he did obſerve the ſame. Let the reader now judge of the poſſibility of my *miſtake*.

64. Mr. Cavallo, p. 320; ſpeaks of errors of my Eudiometers, ariſing from a greater or leſſer preſſure of the column of water, within the tube *d n*. It is very ſingular, that Mr. Cavallo copied my very words, from No. 29, of the firſt edition of this Letter, (and now No. 46 of this edition) into p. 319 of his book: where I preſcribed the very ſame method of avoiding this error, which Mr. Fontana imitated in his Eudiometer, *viz. by raiſing or lowering the tube of the Eudiometer, ſo as to ſee the ſurface of the water in the inſide, even with that on the outſide*, &c. Theſe were my very words quoted by him, in the ſaid page: and this is the very direction he gives afterwards (p. 335), where he ſpeaks of Mr. Fontana's Eudiometer. I am almoſt inclined to think, that Mr. Cavallo poſſeſſes that moſt ſingular talent never heard of before, and of

which nobody elſe but himſelf can boaſt, *viz.* that of *copying*, without *reading* at all what he copies. I will not purſue this ludicrous thought farther, concerning his abilities: but the reader will eaſily perceive, that Mr. Cavallo has his *abſences d'eſprit*, and does not think at all of what he is about, when he writes to depreſs the inventions or contrivances of thoſe, whom he has ſome *ſecret reaſons* to diſlike.

65. Another error Mr. Cavallo remarks in my firſt Eudiometer (ſame article, p. 320) is a very curious one indeed! It conſiſts *in the very act of putting the ſtopple* in: but this error is of ſuch an extraordinary nature, and, if you pleaſe, of ſuch a ſublime kind, that, whilſt he is contented with explaining himſelf in ſuch a myſterious way, I muſt leave it to be contemplated by the reader, at any moments of more leiſure than I generally have.

66. Mr. Cavallo adds, in the ſame place, that the *greateſt fault* (this is certainly the *greateſt compliment)* of my Eudiometers, lays in *not admitting more than one meaſure of nitrous air*. No wonder! Mr. Cavallo was not diſpoſed to read the No. 45, and following, of my printed Letter (being No. 92 and following of this edition), where the very contrary

to his aſſertion is expreſſed; *viz.* the method of employing as many meaſures of nitrous air as one pleaſes. But even independent of having a larger tube, is there any body who knows not, that by making uſe of *ſmaller* and *ſmaller* meaſures of air, the very ſame tube may receive *larger* and *larger* numbers of them? Muſt one be always chewing common food, like nurſes, for little babies?

67. I cannot help ſmiling at a period of Mr. Cavallo's (p. 329), where he ſays, *Mr. Fontana contrived a meaſure, which is the only inſtrument hitherto known, that is capable of meaſuring always a conſtant quantity of elaſtic fluid.*—Is not the method I have given, much before this *wonderful* invention (p. 23, note *g* of the firſt edition, and page 39, note *q* of this preſent edition) equally effectual, with this only difference, that mine is infinitely more ſimple, and cheaper, ſince it coſts nothing?—Let the public judge. This *great invention* calls to my recollection the humorous print, publiſhed ſome years ago; where all the mechanical powers, and a great complicated machinery was repreſented, as employed to draw out—what?—the cork of a bottle!

68. I come now to the *laſt fault* of my Eudiometers, which Mr. Cavallo did not honour with the epithet of the *greateſt*; notwithſtanding that it alone ought to damn them compleatly, if it really exiſted, as he pleaſes to aſſert, with that candour which I never expected from him indeed!

69. He ſays (p. 327), that with my Eudiometers, one cannot depend upon greater accuracy than about one 13th part of the whole. But, as I have ſaid above, that Mr. Cavallo is ſometimes *abſent from himſelf*; it will naturally follow, that his actions, at that time, are not his own: and wrong or bad as they may happen then to be, they muſt not be attributed to his own principles. The true fact was as follows. Mr. Cavallo told me once, that he could not obſerve, *that increaſe in bulk of the two mixed airs* abovementioned, No. 60. I anſwered him, that I was certain of the fact; and that I thought, I was able to demonſtrate it to him at any time. Accordingly, Mr. Cavallo called at my apartments one day for *this purpoſe:* and indeed I did not ſuſpect in the leaſt, that he came for *any other*.

70. It happened, however, that the circumſtances were not as they ſhould be, to produce the ſaid phænomenon, which I had already endeavoured to repeat a little before he came, without ſucceſs: but certainly, I did not *acknowledge*, as he inſinuates, that I had been *miſtaken*. This ſuppoſed *acknowledgement* is, and muſt be *falſe*; what I then ſaid, was only this, *that not obſerving the ſame phænomenon as before, I could not at preſent account for it*; *and that, in all probability, it depended upon ſome circumſtances, which had not been properly attended to.*

71. Mr. Cavallo ſeemed to acquieſce in this matter: and deſired (with what deſign, I did not then ſuſpect) to ſee, how I worked with my Eudiometer. I complied with his requeſt in a careleſs and unguarded manner, by no means intending, as he ſays, to try the quality of the air out of my window. Indeed, I had not, nor could I have at that moment, any other view than ſimply to ſhew my own management or manner of handling the inſtrument; but Mr. Cavallo took care to note the reſults. On this, however, I put not the leaſt bad conſtruction; although I now ſee, it was intended merely to cenſure the whole proceſs.

72. Now, I appeal to Mr. Cavallo's candour, (unleſs he is ſtill abſent from himſelf), whether this is, or is not, the true ſtate of that tranſaction?

But, at the ſame time, I do appeal alſo to all Experimental Philoſophers in the world, whether in any ſuch trials, as theſe he rightly deſcribes (pp. 326, 327), of four experiments, made in ſuch an *unguarded* and *careleſs* manner, one of which gives a reſult ſo widely different from the three others, as 48 to 58: whether, I ſay, they ſhould not exclude it from the other three; and ſhould not ſuſpect it, as proceeding from ſome inattention or miſtake in the operation? This is a rule dictated by common ſenſe, and generally adopted by true Experimental Philoſophers; from which, if Mr. Cavallo deviates, in his experiments of any kind, nobody can expect any thing but numberleſs blunders and the moſt egregious abſurdities in all his aſſertions.

73. Then, if we exclude, as we ought to do, the experiment of 58 degrees or diviſions according to my ſcale, from the other three, *two* of which gave 48, and only *one* 51 diviſions; we ſhall find, that the mean reſult is no more than 49. It is therefore evident, that the whole variation of thoſe trials does not a-

mount to more than *one* part in 132 of the ſcale. And this ſeems the moſt reaſonable calculation, as there were *twice* 48, and *only* once 51, in the three experiments.

Now let the reader judge for himſelf of the *fair concluſion* Mr. Cavallo draws from hence about the *unfitneſs of my Eudiometers for the purpoſes they are intended to anſwer!*

74. But at the ſame time let the reader judge alſo of the accuracy and conſiſtency of of Mr. Cavallo with himſelf, by aſſuring the public, (p. 328), that the accuracy of Fontana's Eudiometer is ſuch as can hardly be believed; and that it's error very ſeldom amounts to one fiftieth of a meaſure; whilſt in mine, by the very careleſs experiments he witneſſed, if they are duly calculated, it amounts to no more than to one ſixty-ſixth of one meaſure, or to one 132d of the two. In all probability, the mind of Mr. Cavallo was at that time on it's rambles; I mean, he was *abſent* from himſelf; and conſequently he overlooked what he was about to write.

75. Finally, let us examine, if poſſible, how it comes to paſs, that modern philoſophers in general agree, that, by mixing the very ſame meaſures of ſimilar *nitrous*

and *common air*, their bulk is very often unequally diminiſhed at each time: how comes it to paſs, I ſay, that this general and incontroverted fact is fruſtrated by Fontana's Eudiometers? Is there any man of common ſenſe, except Mr. Cavallo, and the like philoſophers, who would not directly conclude, that there muſt be ſome cheat or other in the performance of this inſtrument, to ſhew the very reverſe of what happens, when the ſame experiment is performed in the ſimpleſt and plaineſt way?

76. Dr. Prieſtley and I, as well as almoſt all other experimenters, Mr. Cavallo and his friends only excepted, always put together two or more equal meaſures of nitrous and common air, in a veſſel large enough to let every one of their particles come into contact with each other: and afterwards throw them into the meaſuring tube. By repeating the experiment ſeveral times, with the very ſame circumſtances, and with equal care, we generally find, there is very often a ſenſible difference between ſome of the experiments: but we take a medium of them all, to form our judgment. Mr. Cavallo, however, and other Fontaniſts, inſtead of putting both airs together in a large veſſel, to give room to their reciprocal action, throw one air after the

other into a narrow tube, where only can be had a partial action between the two aerial fluids; and then they are very happy to find that *almoſt conſtant* reſult of their repeated experiments, they glorioufly boaſt ſo much of.

77. Strange happineſs indeed! If we always find, that *guineas* are heavier that *ſhillings*, and ſee that a balance ſhows them of one equal weight; ſhould we not think, with the utmoſt reaſon in the world, that ſuch a conſtant appearance muſt be a meer cheat in the balance itſelf? Is not this ſimilar to the tricks of Jones, Comus, Breſlaw, and Katterfelto, who make things appear what in reality they are not?

78. There is ſomething remarkable in what Mr. Cavallo ſays, (p. 327), *viz.* that *I acknowledged to him*, that I had deſpaired of obtaining a conſtant reſult from theſe experiments with nitrous air. But, after my having acknowledged the ſame *uncertainty* to all the world, in the very firſt (page 26) and following editions of this letter; one may be apt to think, that Mr. Cavallo has overlooked it; and that he miſtook what I had ſaid to him, as if it was a *ſecret* or *a friendly confidence*, of which he had the *generoſity* of availing himſelf, by diſcloſing it to the public, to expoſe

my poor Eudiometers. If ſo, he was guilty of an unhappy overſight indeed!

79. Now, if we combine with this probable fact, the peculiar advantage that Mr. Cavallo has endeavoured to draw from the *unguarded experiments*, he came to ſee in a *friendly manner* at my lodgings:—when it is conſidered, that I was treating him with the moſt friendly regard, whilſt he was muſtering together ſuch a heap of doughty arguments againſt my poor Eudiometers: and that I have continued ever ſince the ſame behaviour towards him, whenever we met together, without his having uttered a ſingle word of what he was doing, or ever afterwards making the leaſt excuſe for what he had done:—I cannot help judging theſe circumſtances deſerve to be known, that the public may form a true eſtimate of the whole.

Deſcription of another NEW EUDIOMETER.

80. This Eudiometer is the neareſt to your original one: and after the material improvement I have lately made in it, I cannot heſitate to conſider it now, in my humble opinion, as one of the beſt, both on account of it's ſimplicity and cheapneſs; theſe being two circumſtances,

ſtances, which deſerve to be attended to in all kinds of experiments, as I have noticed in my Letter of the 30th of Novembee, 1776. This, however, I gladly ſubmit to your ſuperior judgment.

81. This Eudiometer conſiſts in a ſtraight glaſs tube *e n* (fig. 8), of an uniform diameter, about one or two feet long, ground air-tight to the neck *e* of a large ball *s*, about three inches diameter, which has alſo an opening *o* in the top, with a ſmall ground ſtopple *t* to it. The lower end *n* has alſo a glaſs ſtopple fitted air-tight to it: and either is wide open like a funnel, or a ſeparate one is to be made uſe of, as ſeen (in fig. 8,) by the pointed ſhape there marked at the lower end *n*. The two necks *e o* of the ball *s*, and the lower end *n* of the tube *e n* may have a braſs ring cemented to each, in order to ſtrengthen them.

82. Beſides this, there muſt be had a divided ruler, (fig. 13) like that deſcribed No. 38; a ſmall ſyphon *g b* (fig. 22), with a braſs ring K: a glaſs funnel *y* (fig. 10), which ſhould be ground to the end *n* of the tube: and finally two ſmall phials, like *z*, (fig. 9), the contents of one being but half of the other; and

ſuch, that both the tube *n e* and the ball *s*, may contain 8 or 10 meaſures of the ſmaller phial.

83. Here I muſt animadvert on what ought to be already done, when I ſpoke of the firſt Eudiometer, viz. the care that is required to be taken, not to leave behind any bubble of air, ſticking to the necks of the inſtrument, nor to the inſide ſurface of the tube and meaſuring pieces of the Eudiometer, before any trial is made; becauſe there is always formed, over a glaſs-ſurface, a kind of an incruſtation, almoſt imperceptible to the eye; which proceeds from the heterogeneous greaſy particles which are floating in water and air, and hinder the cloſe contact between the glaſs and water; ſo that when ſuch glaſs veſſel is emptied, the watery particles that are adhering in certain ſpots here and there, attract the neighbouring particles of water, and form themſelves into drops, which would otherwiſe fall down, if the near ſurface of the glaſs, ſo coated, did not oppoſe their paſſage.

84. This is the true explanation of this phænomenon, ſo commonly obſerved, and ſo little underſtood; even by ſome pretended nice experimenters, or elſe they ſhould not inſiſt ſo much on having the tubes and mea-

ſures for eudiometrical experiments, quite unpoliſhed on the inſide; becauſe as ſoon as this unpoliſhed ſurface becomes covered with that greaſy coating, the ſame large drops will be there formed as before; and their added bulk will defeat the nicety of the true meaſure's being ſhewn by the inſtrument. From hence it is evident, that the remedy does not lay in depoliſhing the inſide of the inſtrument, which is very tedious and tireſome, beſides the cracking and ſpoiling it in the operation, which often happens; but ſimply in well cleaning the inſide, both of the meaſuring inſtrument and of the tube. This is very eaſily done, by rubbing well the inſide ſurfaces with a wet rag, tied round a ſtick or a thick metal wire a little bent at it's end, and powdered either with flour of *emery*, or *potea*, *crocus martis*, *colcothar*, or even only daubed over with *hard ſoap*.

THE PROCESS.

85. The practical way of employing this Eudiometer is eaſily underſtood, by what I have already ſaid of the preceding one.

Firſt, the Eudiometer *n e* (fig. 8) is ſhut up with the ſtopple *t*, in the neck *o*: it is

then

then filled with water: and ſet up in a vertical poſition, with it's mouth *n* open, under the ſurface of the water in the trough (fig. 17).

86. *Secondly*, the largeſt of the two phials *z* (fig. 9) is filled as above directed (No. 41), with the air intended to be tried: and is thrown into the tube, by means of the glaſs funnel *y* (fig. 10), which being ground to *n*, will ſtick there: otherwiſe it muſt be held to it with the hand; unleſs the mouth *n* of the tube be wide enough, not to be in need of any funnel, when any meaſure of air is to be thrown into it, without any loſs.

87. *Thirdly*, the ſame larger phial *z* is filled with *nitrous* air: and this is thrown, in the ſame manner, into the tube *n c*.

88. *Fourthly*, the ſiphon (fig. 22), is added immediately, putting the lower end *b* into the the mouth *n* of the Eudiometer, under the ſurface of the water, ſome of which is poured into it: and the ſtationary moment, ſpoken of No. 45, is watched by means of the ring *K* (ſame fig. 22), ſhaking the ball *s* five or ſix times, that the two airs may be well mixed together.

89. *Fifthly*, when the moment arrives (ſee No. 46) the ſiphon *g h* (fig. 22) is taken off: the Eudiometer is ſhut up with ſtopple *m* (fig. 8) under the ſurface of the water in the trough: and then is inverted with the ball *s* downwards, and the neck *n* upwards, taking care to prevent any bubble of air ſticking to the neck *e* (fig. 8). In this ſituation, the ſtopple *t* is taken under the ſurface of the water from the neck *o*; and the inſtrument is raiſed or lowered, until the inſide ſurface of the water becomes even with the outſide of the water in the trough. *See* No. 46.

90. *Laſtly*, the ſpace occupied by the reſiduum of the diminiſhed air, is meaſured by applying to its ſide the ruler or ſcale (fig. 13): and the reſult is eſtimated after the manner already explained No. 49 and No. 51, having taken care to reſtore the temperature of the diminiſhed air, as noticed at the end of No. 46.

91. The ſame precautions I have ſpoken of (Numeros 45, 47, and 55) muſt be obſerved when this Eudiometer is made uſe of, in order to form a proper judgement concerning thoſe places, where people may be able to live without danger of hurting their conſtitutions, by breathing, and being continually ſurrounded by, noxious air; which they have not yet been

able

able to diſtinguiſh from the moſt wholeſome, except by a long and too late experience. See Note *u* to No. 48.

92. The Eudiometers already deſcribed are the fitteſt inſtruments for philoſophical experiments on the bulk of air and other fluids, when mixed together; and even when mixed with ſome ſolid ſubſtance, which can be introduced into the lower veſſel *c* of the firſt Eudiometers, or in the ball *s* of this ſecond kind. It will be better, however, to have them made purpoſely for ſuch objects, with a tube, two, three, or more times longer than I have indicated above. Or elſe the ſmaller phial already mentioned No. 82, is then to be made uſe of. In this laſt caſe, the very numbers marked in the ſcale (fig. 13) may be employed in the calculation, only taking care to halve them; becauſe this ſmall phial contains but half of the larger one, which is uſed in common experiments.

93. Whenever dephlogiſticated air is to be tried by theſe inſtruments, proper care is to be taken to obſerve the preciſe point of its full ſaturation, which is that of its greateſt diminution by the addition of *nitrous air*.

94. In order to make this experiment with great accuracy, let a narrow glaſs tube of an uniform diameter (fig. 24), be provided: let one of the two phials *a* or *b* (fig. 16), filled with quickſilver, be thrown into it, and the tube cut exactly to that ſize, ſo as to contain neither more nor leſs. Let it's whole length be divided into ſome number of equal parts, by which number the value marked on the ruler (fig. 11), of this Eudiometer, may be divided without any fraction: for inſtance, when the number * * = 108 is marked in the ruler, it means, that the contents of the two phials *a* and *b*, of which I ſpoke No. 49, are equal to a cylinder of 108 diviſions long, as thoſe of the ruler: and, of courſe, it ſhews that a ſingle phial *a* or *b* contains but 54 of theſe parts. In this caſe this tube (fig. 24) may be divided either into 27 parts, each containing two of the ruler; or into 54, into 108, &c.

95. If the top of the tube is not very flat in the inſide, it will be more exact to divide the weight of the quickſilver into two parts; to put one of them into the tube; to mark the ſpace occupied by it; to divide the part of it, which was empty, into half the number intended for this tube; and afterwards to

divide the other half into ſimilar equal parts, as the firſt half, carrying them towards the cloſed end. It is hardly neceſſary to notice, that the very ſame Eudiometer deſcribed No. 37. and following, of a common ſize, will ſerve alſo for theſe experiments; if inſtead of the phials *a* or *b*, any other of a much ſmaller ſize is made uſe of. The Eudiometer being in the poſition repreſented by *fig.* 14, but without the phials *a* or *b*, it will be very eaſy to apply the funnel B. *fig.* 18. to one of the two under holes of *a* or *b*: and to let the ſmaller meaſure of air go ſucceſſively through it into the upper part *x* of the veſſel *c*, &c.

96. If the dephlogiſticated air is very pure, it will require much above the double quantity of *nitrous air*, to be completely ſaturated. In order to do this without exceeding the neceſſary quantity, I throw into the tube *n d* (fig. 17) a ſecond meaſure *b* or *a* of *nitrous air*, after I have brought the proceſs to the moment mentioned No. 46. In this caſe, the whole volume or bulk of the dephlogiſticated and nitrous air, will be 162 [=108+54]. I obſerve where, the ſurface of the inſide water in the tube, ſtops: and I mark it by ſliding the braſs ring *z*. I then fill up the divided tube fig. 24) with *nitrous air*: I throw a ſmall

quantity into the Eudiometer's tube *n d*; and, if it becomes of a reddiſh colour, the incloſed air will diminiſh. I then puſh up the ring *z*: and, by this means, I go on throwing in the nitrous air, by little and little, till I ſee that the whole diminiſhes no more; which ſhews me that it is fully ſaturated.

97. Let us ſuppoſe, for example, that the tube (fig. 24) was divided only into 27 equal parts; and that the ſaturation of the dephlogiſticated air was compleated at the eighth diviſion of it: this ſhews that 19 parts [27—8 =19], equal to 38 of thoſe marked in the ruler, have been thrown into the Eudiometer; that is to ſay, that the whole bulk of both kinds of air is equal to 200 [=162+38] meaſures, as thoſe marked by the ruler (fig. 11.) already explained No. 50. Now if the remaining quantity of air, within the Eudiometrical tube, is only equal to two diviſions or numbers of the ruler; it is clear that ſuch dephlogiſticated air is ninety-nine times of an hundred $\left[\frac{200-2}{200}\ \frac{198}{200}=\frac{99}{100}\right]$ pure air; ſince its bulk is reduced, by the combination of *nitrous air*, to the $\frac{1}{100}$ of the whole.

98. It is but three days ago (z), that you ſhewed me ſuch a wonderful kind of air, as I have exemplified in the preceding article. This air you have produced before my eyes, from a ſolution of *quickſilver* in *nitrous acid*, made many months before, and then diſtilled in a long but narrow glaſs retort, with a ſand-heat. This is, indeed! an extraordinary phenomenon: and ſeems to bring us, perhaps not a little, nearer to the door of the ſecret laboratory of Nature in the formation of air.

99. I cannot ſay, but ſo pure a *dephlogiſticated air* may ſtill be produced by this proceſs; that its whole bulk may be reduced to nothing, by a proper combination with *nitrous air*. If ſo, what ſhall we then be able to think of a fluid ſubſtance, which is coercible in a glaſs veſſel, to which above the double quantity of another ſubſtance $\left[\frac{54+54+38}{54}=\frac{146}{54}=2,7\right]$ likewiſe coercible in a glaſs veſſel, being added; both theſe ſubſtances, to appearance, wholly vaniſh!

(z) This additional article to the preſent letter was wrote on the 16th of September, 1777; although the greateſt part of it had been written many months before, and the firſt twenty numbers were already printed: but ſome circumſtances, the knowledge of which cannot intereſt the public, have hindered, till now, the publication of the whole.

100. This phenomenon certainly deſerves the attention of philoſophers: and I gladly leave to them the examination of it. I muſt only add, for their information, that the *nitrous acid* is the thing chiefly concerned in its production. When this admirable ſubſtance acts on certain kinds of bodies, as *quickſilver* in the preſent caſe, its ſolution produces that *elaſtic*, but *coercible* fluid, which we call *nitrous air*: the reſiduum, kept a long while, being properly urged by fire, gives at laſt the other *elaſtic*, but likewiſe *coercible* fluid, which we call *dephlogiſticated air*: and the combination of both, nearly in the above proportion, produces the wonderful phenomenon I have ſpoken of.

101. I ſhall ſay no more on this matter; and leave it very willingly to be conſidered and unravelled by abler philoſophers than I can pretend to be: and conclude the ſubject of this letter, by aſſuring you that I ſhall be very happy, if the things here treated of ſhould deſerve your approbation: and ſtill more ſo, if they produce the deſired effect I aim at,—the general good of mankind. I am, with the utmoſt regard and ſincere friendſhip,

My dear Sir,
Your moſt obedient and
Affectionate ſervant,

Bowood Park,
January 3, 1777,

J. H. de MAGELLAN.

MVSEVM
BRITAN
NICVM

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